1992 ANNUAL REPORT

Alberta

OIL SANDS TECHNOLOGY
AND RESEARCH AUTHORITY

Alberta

OIL SANDS TECHNOLOGY
AND RESEARCH AUTHORITY

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TO HIS HONOUR
T. GORDON TOWERS
LIEUTENANT GOVERNOR OF THE PROVINCE OF ALBERTA

Sir:

I have the honour to submit the Annual Report of the ALBERTA OIL SANDS TECHNOLOGY AND RESEARCH AUTHORITY for the fiscal year ended March 31, 1992.

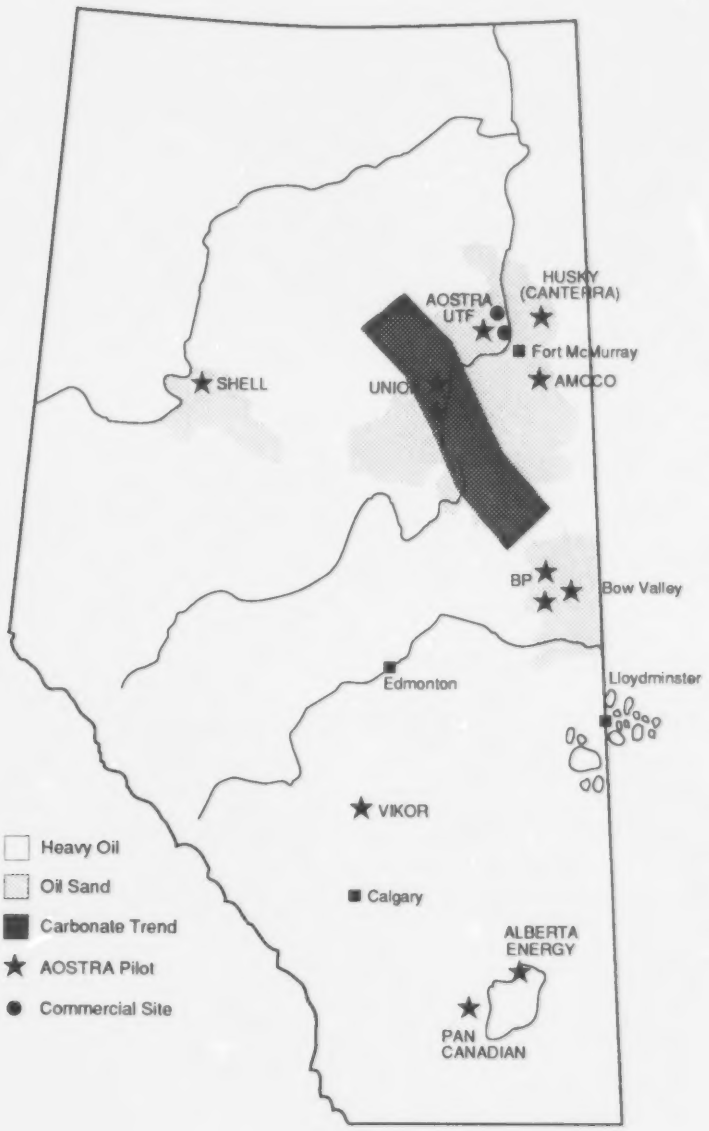
Respectfully submitted,

RICK ORMAN
Minister of Energy

Foreword

On January 14, 1974, The Premier of Alberta announced the availability of $100 million to develop new technology for the recovery and processing of petroleum from the Alberta oil sands. The terms and conditions for the disbursement of these funds are described in the Oil Sands Technology and Research Authority Act, passed by the Legislature in June 1974 and since amended to include the recovery of heavy oils and the enhanced recovery from conventional petroleum reservoirs. Additional funds have since been dedicated by the Alberta Government to permit the funding of longer term programs.

AOSTRA Field Pilot Projects



Report of the Chairman and Chief Executive Officer

To the Honourable Rick Orman
Minister of Energy

Dear Mr. Minister:

I have the honor of presenting the Annual Report of the Alberta Oil Sands Technology and Research Authority (AOSTRA) for the fiscal year ending March 31, 1992.

I am pleased to report that AOSTRA has been able to maintain a very productive technology development and demonstration program in partnership with industry and research agencies during the past year, despite major financial constraints in both the public and private sectors. Fortunately, industry interest in the development of improved technology for future operations has remained high through this period of depressed oil prices and postponement of new commercial projects. However, the maintenance of an effective program has depended greatly on the intensive efforts of Authority Members and staff in selection and evaluation of projects, in adjustment of priorities, and in attracting industry participation. Strong emphasis has been given to technology which has the potential for early commercial application, but every effort has also been made to maintain a balanced program with an effective, if reduced, level of effort in longer range research and specialized manpower training.

The emphasis which AOSTRA is giving to technology of immediate commercial significance is exemplified by the field testing and demonstration of the Steam Assisted Gravity Drainage (SAGD) process for bitumen production. This process is not only applicable to a very large part of the Alberta oil sands deposits at depths below those accessible by surface mining, but also offers the potential for cost savings of 30 to 50 percent over conventional open pit mining and hot water extraction for the shallower deposits, with no tailings ponds or large mined-out areas requiring reclamation.

The first phase tests of the Steam Assisted Gravity Drainage process in the Underground Test Facility in the Athabasca deposit near Fort McMurray utilized three horizontal well pairs each 160 metres in length, with 60 metres in contact with the reservoir. The performance of these well pairs exceeded predictions in terms of production rates, steam/oil ratios, and total recovery of oil in place. The project has now entered the Phase B precommercial pilot stage employing three well pairs, each with 500 metres of horizontal length in contact with the reservoir, which are designed to serve as the prototype for a commercial operation. The drilling and accurate directional control of these wells were accomplished successfully with the use of the drill rig which has been specially developed for operation from tunnels in the underlying limestone.

All three well pairs have now been steamed and placed on test production, and full operation will be started when the steam generation and production treatment facilities are completed in the autumn of 1992. The expected bitumen production rate from the three well pairs is 2000 barrels (300 cubic metres) per day, and their operation over the next four years will provide the information needed for the design and economic evaluation of a commercial project. The surface facilities have been so designed that they will be reusable in a 10,000 barrel per day project.

Nine petroleum companies and the Canadian Centre for Mineral and Energy Technology (CANMET) of Energy, Mines and Resources Canada are now participating in the Phase B program. The industry participants include two overseas companies, JAPEX Canada Limited and the China National Petroleum Corporation (CNPC), both of whom have established offices in Alberta. In addition to acquiring use rights to the technology, the participating companies will earn a share of the oil sands lease on which the Underground Test Facility is situated, as an added inducement to undertake commercial operations. One result of this strong industry participation is that the project was carried out at no net cost to AOSTRA during the past year. Arrangements have been made to sell the bitumen produced in the Phase B program to Syncrude Canada Ltd., and it is also expected that Syncrude will become an associate participant in the project. To maintain the momentum toward an eventual commercial project, a Commercial Plant Study has been initiated with the participants which will develop a design basis for a project, optimize the process in accordance with the Phase B results, and identify an organizational structure and an industry operator for a commercial project.

As another application of steam assisted gravity drainage which may find early commercial use, a joint study has been carried out with a major oil sands mining operator to evaluate the potential for producing bitumen from surface mineable deposits by this method. This study has confirmed that SAGD with underground access is a practical and economical method of recovering bitumen from parts of an oil sands lease which are not readily accessible by conventional surface mining methods, including areas covered by tailings ponds. Consequently, the SAGD approach can serve as a valuable adjunct to existing surface mining operations as well as representing an alternative production method for future projects.

Another and potentially very important application of steam assisted gravity drainage is to horizontal well pairs drilled from the surface instead of from mine tunnels. Negotiations are currently under way for AOSTRA participation in a field pilot project in the Peace River deposit using this approach. The well-control problems involved in the surface access approach are being investigated, since these will be substantially different than for wells discharging into an underground gathering system. Numerical simulation studies have also been carried out in collaboration with operating companies in the Cold Lake area to evaluate the feasibility of utilizing SAGD technology in that deposit with surface drilled wells.

The second area of intensive activity directed toward commercial use of AOSTRA technology is in the various applications of the AOSTRA Taciuk Process (ATP). This process was originally developed for the production of partially upgraded bitumen from mined oil sand, and there is renewed interest within industry for its use in future commercial projects. The ATP could be used as the main extraction process, in which application it would offer the advantages of direct production of a pipelineable oil, the elimination of tailings ponds, and modular construction which facilitates stepwise capacity additions. Alternatively it could be used as an adjunct to other extraction processes to handle low grade or difficult-to-process ores. In order to facilitate evaluation of the ATP by prospective users, a 60 barrel per day mobile processor has been constructed which can be taken to a site to demonstrate its performance with locally mined oil sands or other feed materials. This unit will be officially commissioned in conjunction with the AOSTRA–Canadian Heavy Oil Association Conference in June 1992, and oil sands processing demonstrations will be held for industry and government representatives.

The ATP is equally effective as a process for recovering liquid hydrocarbons from oil shales. Test work and a preliminary cost analysis for the production of synthetic crude oil from oil shale deposits in Saskatchewan have indicated that such an operation would not be economically attractive at current oil prices. However, the situation is significantly different in some other parts of the world and the ATP has been licensed for a proposed 5000 barrel per day semicommercial project in a rich oil shale deposit in Queensland, Australia. Design and engineering work for this project are being carried out by an Alberta company, and the fabrication of key components of the plant would also be done here.

The most active commercial applications of the ATP are in the spin-off area of oily waste treatment, where the process yields an oil-free, safely disposable residue as well as recovering saleable oil if hydrocarbons are present in sufficient quantity. The 10 ton per hour commercial ATP unit described in my previous report has now completed the cleanup of 40,000 tons of oil- and PCB-contaminated soil at the site near Buffalo, New York, and is in the process of starting up at a new site in Waukegan Harbor, Illinois, where 20,000 tons of dredged material from the harbor are to be treated. As an important step toward wider use of the ATP in site remediation and waste treatment, the U.S. Environmental Protection Agency has approved the process itself and also the chemical dechlorination method of destroying PCBs within the processor. The Alberta company which has worked with AOSTRA in the development of the ATP has been granted a worldwide license to market the technology commercially for contaminated soil remediation. This company is currently pursuing applications such as refinery site clean-up in Canada through a newly formed subsidiary. AOSTRA's international contacts have led to the identification of numerous potential applications in other parts of the world, particularly in countries where there have been few environmental controls in the past.

The 60 barrel per day mobile processor mentioned earlier is intended to be used primarily for demonstrating the ATP as an oil sands extraction and primary upgrading process, to encourage industry interest in this application. However, it will also be used in demonstration projects to clean up hydrocarbon-contaminated sites in Alberta and in other waste disposal applications such as municipal solid wastes and rubber tires.

The third area where AOSTRA is undertaking a major thrust toward the development and demonstration of improved technology is in bitumen upgrading. Increased upgrading capacity within Alberta is essential if the oil sands industry is to reach its potential and if the maximum economic returns are to be obtained for the province. The export of raw bitumen suffers from limited accessible markets, low and variable netbacks to producers, and minimal value added within the province. At the same time, the construction of new synthetic crude plants using currently available technology is not attractive at present world oil prices and may not become so before the end of the century. Major strides have been taken in reducing the costs of raw bitumen production through new technology such as the SAGD process, but similar reductions in upgrading costs have not yet been achieved.

A further impediment is that the market for synthetic crude of current quality is approaching saturation as a result of its disadvantages as a feedstock for conventional refineries. Despite its very low sulphur and zero residual content, synthetic crude is discounted relative to conventional light crude and the price differential will probably grow with time as refiners are required to meet increasingly stringent fuel specifications as well as increased demand for motor fuels relative to other fuel products. Consequently, new upgrading processes must not only reduce costs but also yield a synthetic crude with an increased ratio of naphtha to middle distillates and a lower aromatics content.

For some years, AOSTRA has conducted joint studies and feedstock tests in partnership with industry to evaluate new upgrading processes which have become available from process developers throughout the world. These programs have led to the identification of high-conversion

hydrocracking processes as the most promising routes to increased yields and higher product quality. At least partly as a result of this work, all three of the recently constructed or expanded upgrading plants in Western Canada have used some form of hydrocracking process. Research carried out jointly with the Alberta Research Council has led to improvements to current hydrocracking technology which are now being tested, and also to an entirely new high-conversion hydrocracking process which is showing much promise at the small pilot scale. At the other end of the spectrum, consideration is being given to processes such as the ATP operating as a primary upgrader, which might be used on a small scale to convert bitumen from individual in situ projects to a pipelineable product for secondary treatment at a central upgrader.

Continued emphasis is being given to the environmental aspects of all of AOSTRA's initiatives. Fossil fuel production and use have become frequent targets of popular concern, particularly in the case of heavier hydrocarbons such as coal and oil sands bitumen. However, I am confident that all of the current and projected problems are capable of technological solutions, and that we can have true sustainable development of Alberta's energy resources with economic benefits and acceptable environmental quality. The technologies developed for this purpose will have important export potential as well as meeting local needs.

The goals of AOSTRA's environmental initiatives cover virtually all of the important problem areas: elimination of the need for large tailings ponds and amelioration of existing tailings sludge accumulations; minimization of surface disturbance; treatment of oil field wastes; reuse of produced water from steam in situ operations to minimize fresh water consumption and contaminated water disposal; bitumen production processes with reduced energy requirements; upgrading to higher quality fuel products to meet increasingly stringent standards; and capture and productive use of carbon dioxide from combustion and process sources. The capture and use of carbon dioxide as a method of reducing "greenhouse gas" emissions has attracted much interest, with 22 companies and government agencies participating in the current project. Carbon dioxide has been demonstrated to be a very effective enhanced recovery agent, and two of AOSTRA's joint projects with industry have now evolved into commercial projects: the Vikor Joffre miscible carbon dioxide flood and the Ulster Petroleum Retlaw Manville immiscible carbon dioxide flood.

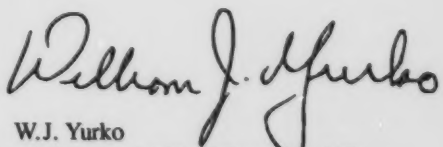
AOSTRA also continues to be very active in the international sphere. A notable success has been the productive technical cooperation which has been established with China, culminating in the recent decision by the China National Petroleum Corporation to become a full participant in the Underground Test Facility project. Other benefits of AOSTRA's international program are to make the most promising technology from other parts of the world available for the development of Alberta's oil resources, and at the same time to work with Alberta industry in marketing AOSTRA-developed technology worldwide.

AOSTRA's policies of developing and demonstrating new technology in partnership with industry have led to a number of commercial projects in Alberta; in addition to those already mentioned, these include the Shell Peace River In Situ Project, the BP/Petro-Canada Wolf Lake In Situ Project, the Norcen Bodo Prototype Scale Heavy Oil Project, and the commercial applications of the AWACT Anti-Water-Coning Technology. There is every reason to expect that other commercial projects will emerge as current development projects mature, particularly with the emphasis now being given to technology with a high probability of early commercial viability. Among the emerging technologies are the much wider application of horizontal wells for all purposes; lower energy in situ production processes such as borehole mining, cold production, and microbiological processes; and advanced bitumen upgrading processes.

The aggressive exploitation of technology which is now at or near the commercial stage, together with the ongoing development of new technologies, will make it possible to maintain Alberta as Canada's leading producer of liquid fuels as conventional production declines.

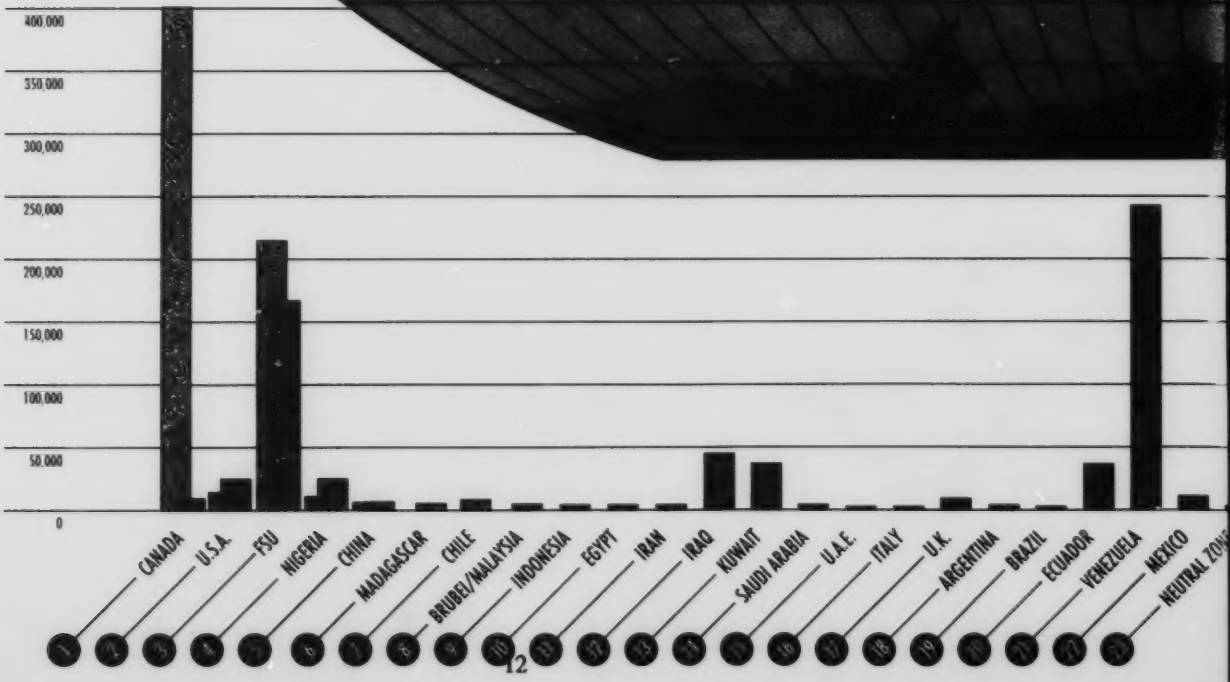
The challenge posed by the limited availability of development funds in both the public and private sectors will require that the most productive use be made of all the available technological capabilities and resources. This may be expected to involve a continued trend toward carrying out most large projects on a multi-industry basis, and increased use of networking among different types of organizations with common interests in a field. It is satisfying to note that AOSTRA has been one of the most successful agencies in Canada in organizing productive multicompany projects and in forging links among industry, institutional, and university research groups. An excellent example is the AOSTRA/Alberta Research Council/CANMET/Industry Research Program, which brings together the experience and resources of industrial, federal, and provincial research organizations and also provides very attractive financial leverage for the individual industry participants. I am confident that with continued support by the Government of Alberta and a continuation of our effective collaboration with industry and other research organizations, we can maintain Alberta as a world leader in non-conventional oil technology and as a major producer which can successfully compete in world oil markets.

Respectfully submitted,



W.J. Yurko
Chairman and Chief Executive Officer

Heavy oil and oil sands re



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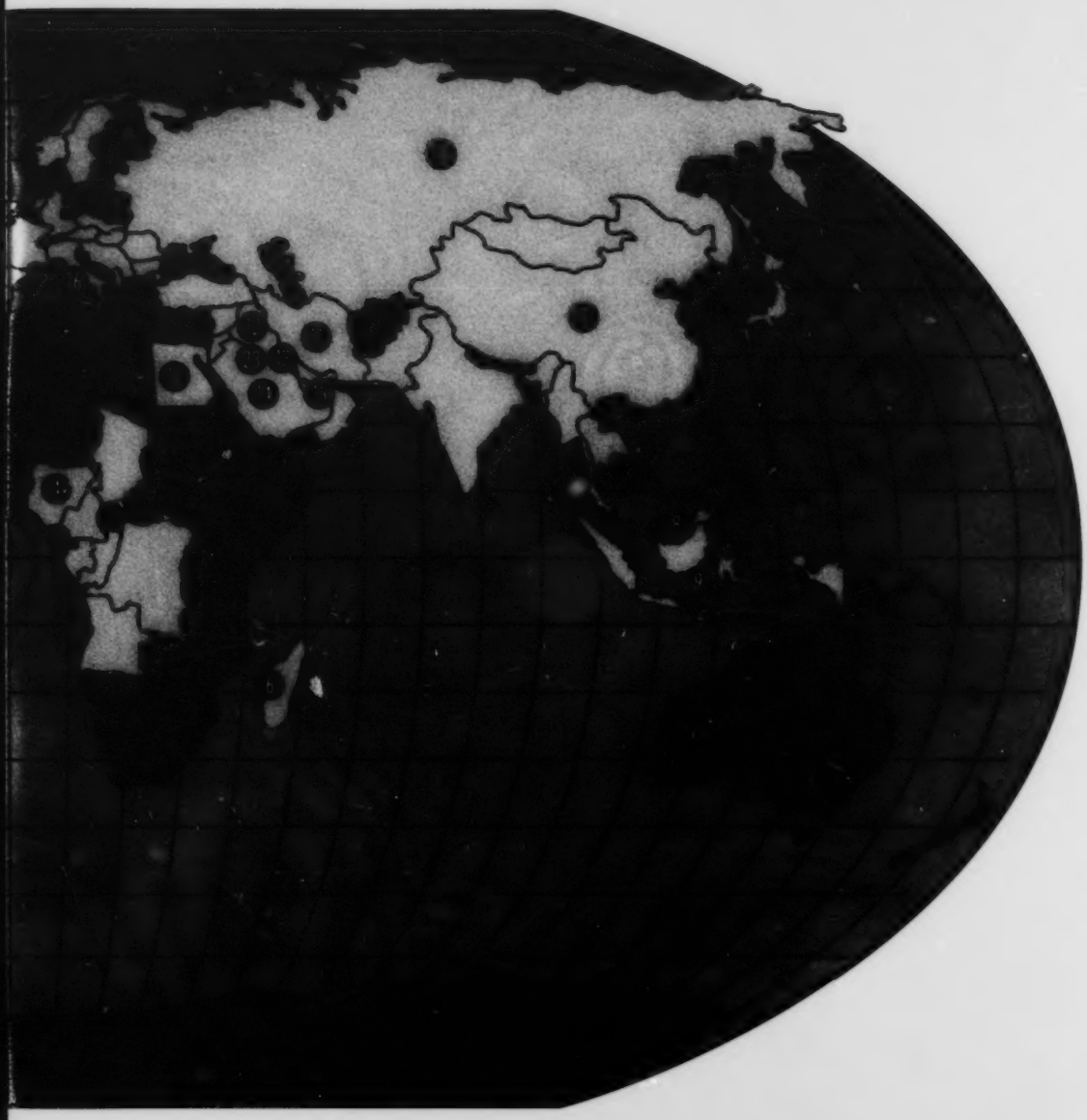

250,000
200,000
150,000
100,000
50,000
0

COUNTRIES WITH OIL SANDS AND/OR HEAVY OIL

OIL SANDS (X 10^6 m^3)

HEAVY OIL (X 10^6 m^3)

The Honourable Rick Orman
Minister of Energy

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Report of Activities

1 IN SITU OIL SANDS RECOVERY PROGRAM

1.1 AOSTRA-Amoco Gregoire Lake Pilot Project

In 1984, Amoco Canada Petroleum Company Ltd., with AOSTRA and Petro-Canada Exploration Limited as participants, initiated operation of the Gregoire Lake in situ pilot on a site approximately 15 km northwest of the former Block 1 pilot which earlier tested the COFCAW process. The project, consisting of a four-spot pattern of injection, production, and observation wells, commenced operation in 1986 using steam and steam additives to recover bitumen from a 41-m thick McMurray sand reservoir located at a depth of 190 m. Initial heat front movements in the reservoir were tracked through the application of 3-D seismic monitoring over the 0.28-hectare pilot area. In 1988, foam surfactants were injected to improve steam sweep efficiency.

The project was extended in 1990 with AOSTRA and Amoco as participants to evaluate further steam cycles, surfactant injection, pressure cycling, of the reservoir and the effect of low-temperature oxidation on plugging of the steam channel with air-steam injection. Project operations were completed in July 1991 and the project facilities were suspended pending further developments. The project demonstrated that reservoir sweep efficiency was improved by foam injection and that sustainable production rates would be achieved by cyclic steam injection. Due to budgetary constraints, project operations were not extended. AOSTRA's share of costs in these projects amounted to $18.9 million.

1.2 AOSTRA-Bow Valley Cold Lake Pilot Project

Bow Valley Resource Industries Ltd. and AOSTRA participated in the operation of a pilot in the Cold Lake area of northeastern Alberta to test the recovery of bitumen from the Clearwater Formation. The first phase of the pilot tested the use of superheated steam, carbon dioxide, and a clay stabilization additive for the recovery of bitumen. The ramped steam injection process was successfully tested. Encouraging results led to the development of a second phase on larger spacing to further test the process. The extended project was operated until August 1990. Plans for the development of a commercial prototype project were terminated at that time because the economic feasibility of cyclic steam injection could not be demonstrated due to low heavy oil prices. A final report has been prepared for the project. AOSTRA funding for the project was $13.9 million.

1.3 AOSTRA-BP Marguerite Lake and B-Unit Pilot Projects

The Marguerite Lake pilot project was operated by BP Canada Exploration Ltd. with AOSTRA, Dome Petroleum Limited (now Amoco Canada Petroleum Ltd.), and PanCanadian Petroleum Limited as participants. The project, which started in 1978, tested steam stimulation followed by wet combustion in the Clearwater sandstone formation of the Cold Lake oil sands deposit. Later, oxygen combustion was also tested. The steam recovery technology developed at the Marguerite Lake pilot is being applied in the Wolf Lake commercial project which started in 1985 and surrounds the pilot area. The cost of the project to AOSTRA was $24.0 million.

BP also operated the B-Unit pilot project with AOSTRA and Petro-Canada as participants. Single-well cyclic steam stimulation was tested in a single-well project in the Lower Grand Rapids Formation of the Cold Lake sand deposit. A 22-well steam stimulation project was developed by BP and Petro-Canada in the Grand Rapids Formation at a location adjacent to the Wolf Lake operation based upon encouraging results of the B-Unit pilot. AOSTRA's one-third share of total project costs of $3.45 million was $1.15 million.

Steam and combustion technology developed in these projects, including oxygen combustion technology, is available for licensing.

1.4 AOSTRA-Husky Kearl Lake Pilot Project

Husky Oil Operations operated the Kearl Lake project with AOSTRA and Esso Resources as participants. The pilot tested a steam drive process in the McMurray oil sands on a site located 80 km northeast of Fort McMurray. The pilot consisted of two patterns. The "A" pattern was an inverted seven-spot pattern with seven steam injection wells and six producers which began operations in 1981. In 1985, the "B" pattern consisting initially of an inverted nine-spot pattern was developed based upon information from the "A" pattern. After two years of steam injection, the "B" pattern was expanded in 1987 with the addition of two adjacent inverted five-spot patterns. Special fracturing techniques were employed in the two new patterns and steam additives were tested. A method for controlling steam outflow from the "B" pattern was also tested. Production operations continued

until April 1991 when project operations were completed. While project production performance was encouraging, an evaluation of further development options indicated that commercial development was not economically feasible under current market conditions. The production facilities have been suspended in anticipation of future project use. AOSTRA funding for the project was $53.2 million.

1.5 AOSTRA-Shell Peace River Pilot Project

Shell Canada Resources Limited operated the Peace River in situ pilot project with AOSTRA, Shell Explorer Limited (now Pecten Canada Limited), and Amoco Petroleum Canada Ltd. as participants. The project, located 30 km northeast of Peace River, was designed as a prototype installation to test a modified steam drive process on the Peace River oil sands. The recovery technology was based upon cyclic steam pressurization and modified steam drive in a thick oil zone underlain by a bottom interval of high water saturation. Successful testing of the recovery process was completed in 1985. Using the pilot project technology, which indicated oil recovery in excess of 55%, Shell Canada developed a commercial project with a producing capacity of 1600 m^3/d. AOSTRA received data from the commercial operations until October 1989. AOSTRA funding for the project amounted to $75.0 million.

1.6 AOSTRA-Unocal Buffalo Creek and McLean Pilot Projects

Unocal Canada Limited, with AOSTRA and Canadian Superior Oil Limited (now Mobil Oil Canada, Ltd.) as participants, operated the Buffalo Creek and McLean pilot projects which were located 100 km west of Fort McMurray. Tests were conducted in the Grosmont 2 and 3 Devonian carbonate formations starting in 1977 to determine the suitability of steam stimulation, steam drive, and wet combustion processes for bitumen recovery. The programs produced mixed results and the project was suspended in 1986. AOSTRA's share of funding for these projects has been $31.4 million. Because of the large bitumen reserves in the carbonates, AOSTRA is studying the potential of the carbonate area with the ultimate goal being the development of a new project in this huge resource.

1.7 AOSTRA Data Base System

AOSTRA has an ongoing project called the AOSTRA Data Base System (ADBS) that has two main objectives:

- Storage of data collected from AOSTRA/industry projects.
- Provision of software suitable for manipulation of project field data.

ADBS has been in operation since 1980 and over 225 project-years of data, representing the detailed operations of more than 20 projects, has been obtained. Data volume within ADBS increased 18% during fiscal 1991/92. Projects include pilot, semicommercial, and commercial operations.

AOSTRA arranges project-specific procedures for acquiring data from project operators. The majority of the data are numerical and represent the results of well and plant operations. ADBS stores both raw data and calculated or summary data suitable for reporting. Recently, textual data was included to provide abstracts of reports, papers, patents, and other written material.

Users of ADBS include both industry and AOSTRA internally. All data are confidential and available on a project-specific basis to project participants. Authorized users can access the data via "dial-up" to AOSTRA's Calgary Computing System on a fee-for-service basis, or by licensing the ADBS software for use on user systems.

ADBS is designed as a workstation and client-server application within a UNIX™ operating system environment. There are several components to the system including data loading and updating, report generator, standard query language, and workstation graphics via the AOSTRA Graphics System (AGS). During the past year, AGS was enhanced to include 3-D graphics in the form of contours and surfaces. AGS works well for the display of both project data and numerical simulation results. A new ADBS product was also developed called the "Job Scheduler" which provides effective load balancing of computing jobs within a local area network. All ADBS components can be accessed via a graphical user interface on computers supporting the "X Windows" environment.

Inquiries on AOSTRA's project data bases and the use of the AOSTRA Data Base System are welcomed. Information brochures are available from AOSTRA's Computing Services section at the Calgary office.

2 HEAVY OIL RECOVERY PROGRAM

2.1 AOSTRA–Alberta Energy Suffield Heavy Oil Pilot Project

Alberta Energy Company Limited (AEC) operated the Suffield heavy oil combustion project on behalf of AOSTRA, Amoco Canada Petroleum Company Ltd., and Westcoast Petroleum Limited. The fireflood was conducted in the Glauconitic sandstone reservoir under the Suffield military block in southeastern Alberta. The project terminated in 1986. While production from the combustion pilot was greater than that which would be expected by primary recovery alone, further combustion testing was not warranted. However, an alternate recovery process was identified during the combustion project.

An analysis of the combustion project led to the development of anti-water-coning technology (AWACT) that was further developed and tested by AEC, AOSTRA, and Westcoast Petroleum in 1987 and 1988. The AWACT technology is now being applied commercially and can be licensed from AOSTRA for application by interested companies.

An additional heavy oil recovery test was started in 1989 when AEC and ARC and Westcoast Petroleum initiated a hot waterflood in an inverted four-spot pattern in the Suffield Block. The hot waterflood project ended on December 31, 1990, and the results are being analyzed for summary in a final report. AOSTRA's share of costs for the above three projects was $7.4 million.

2.2 AOSTRA-Mazzei Frog Lake Pilot Project

AOSTRA initiated a project in early 1990 with Mazzei Oil Inc. as operator in the Frog Lake area of east-central Alberta. The project tested the cyclic steam stimulation of the Mannville Formation in the Lloydminster heavy oil sands. Two cyclic steam injection tests were conducted on two wells. The production results of the steam stimulation tests were compared to the results of heating by electromagnetic methods in two adjacent wells. A post production analysis has been conducted and a final report summarizing the results has been completed. The tests indicated that steam/oil ratios were too high to be economically attractive for cyclic steaming in this reservoir. However, good interwell communication and increased production in offsetting production wells suggested that steamflooding might be practical in the area. AOSTRA costs for the project were $489,844.

2.3 AOSTRA-Norcen Bodo Field Pilot

Norcen Energy Resources Limited, on behalf of AOSTRA, Esso Canada Resources, Murphy Oil Company, and Canadian Occidental Petroleum Limited, operates the Bodo steamflood project in east central Alberta. The test is being conducted in a 15-m thick McLaren sand in the Upper Mannville Formation at a depth of 720 m. The steamflood has a nine-spot configuration similar to the configuration of an offsetting pattern in which a combustion project was conducted in 1984. The results of the steamflood project will be compared to the results of the earlier combustion project. Since initiation of the steamflood in 1985, four cycles of steam injection have been completed. The cyclic steam injection was followed by a steamflood which will continue through year 1992. The results of the cyclic steam operation and the steamflood have been encouraging and the project produced its one millionth barrel of oil in December 1990. AOSTRA's net costs for the project are $3.7 million.

3 ENHANCED OIL RECOVERY PROGRAM

3.1 AOSTRA-Amoco Cessford Caustic Polymer Flood

Amoco Canada Petroleum Company Ltd., on behalf of AOSTRA and CS Resources Ltd. (formerly Sulpetro), operates the Cessford caustic polymer flood in the Cessford Basal Colorado "A" Pool, which is approximately 180 km east of Calgary. The field project was initiated in 1986 after single-well tracer tests in 1980 and subsequent laboratory tests indicated that residual oil after waterflooding could be recovered by caustic polymer flooding. The injection of the caustic-polymer slug was completed in 1990. Fresh water is now being injected in the project and will continue through 1992. Encouraging production results have been observed in two of the three areas in which caustic polymer has been injected. The gross costs for the incremental caustic polymer waterflood were estimated to be $4.9 million. AOSTRA's 50% share of project costs have been $2.4 million to date.

3.2 AOSTRA–Beau Twining Rundle Pool Horizontal Well

Beau Twining Petroleum Ltd., as operator, with AOSTRA as a participant, drilled a long-radius horizontal well into the Twining Rundle Pool which is located approximately 90 km northeast of Calgary. The purpose of the test was to assess the commercial feasibility of exploiting low-permeability reservoirs with horizontal wells in an area where vertical wells have low productivity. The well was successfully drilled in 1991 and the production potential is now being tested. AOSTRA's share of project costs to date is $476,262.

3.3 AOSTRA–Canadian Hunter Ethel Lake BHL Pool Horizontal Well

In 1988, Canadian Hunter Exploration Ltd., with AOSTRA as a participant, drilled a long-radius horizontal well into the Ethel Lake "BHL" Pool. The purpose of the test was to assess the commercial feasibility of exploiting low-permeability oil-bearing carbonate reef reservoirs with horizontal wells in an area where vertical wells have proved non-commercial. The well was successfully drilled but poor reservoir quality was encountered and the expected production potential will not be realized. The cost to AOSTRA for the project was $712,000.

3.4 AOSTRA–D.B. Robinson Slim Tube Study

AOSTRA operated a cooperative industry-supported research program to investigate the use of slim tubes to evaluate conditions of miscibility in miscible floods. The objective of the project was to demonstrate the feasibility of collecting and analyzing small samples of flowing fluid in a slim tube, particularly in the transition zone between the solvent and the oil. The project was financially and technically supported by nine industrial companies and AOSTRA. D.B. Robinson and Associates Ltd. was the contractor for the project. Specialized equipment was designed and fabricated in Edmonton for the project and a series of slim tube tests were conducted. A final report has been issued for the project. The project was completed at a cost of $288,860; AOSTRA's share of costs was $192,475.

3.5 AOSTRA–Gulf Fenn–Big Valley "D3B" Nitrogen Injection Project

Gulf Canada Limited and AOSTRA participated in a nitrogen injection project in the Fenn–Big Valley "D3B" pool located approximately 80 km east of Red Deer. The project was initiated in 1987 with Gulf as operator of the project. Nitrogen was initially injected into the small Devonian reef reservoir to determine if the recovery of oil, natural gas liquids, sulphur, and gas could be improved by the maintenance of reservoir pressure and the stabilization of fluid interfaces. The project was extended in 1989 to test the effectiveness of nitrogen foam injection to further enhance recovery. Post project production data are now being gathered for an analysis of the process. AOSTRA's 50% share of project costs to date has amounted to $857,779.

3.6 AOSTRA-Husky Asphaltene Solids Precipitation Studies

Husky Oil Operations Ltd. and AOSTRA jointly supported a laboratory research program to study the precipitation of asphaltene solids in selected light oils when contacted by hydrocarbon fluids typically used in solvent floods. The project was operated by Husky and conducted by Hycal Energy Research Laboratories of Calgary as contractor for the project. The study was completed in 1990 at a cost of $310,480 which was funded 50% by AOSTRA.

A mathematical model was formulated to predict the deposition of asphaltene solids under various pressure and temperature conditions using an equation of state and data obtained from asphaltene solubility tests. A PC computer program was developed for the prediction of asphaltene precipitation based upon the mathematical model. The study results and program are available for licensing to interested parties.

3.7 AOSTRA-PanCanadian Countess "B" Combustion Pilot Project

PanCanadian Petroleum Limited and LL&E Canada Limited are participants in the Countess "B" combustion pilot which is being conducted to evaluate a wet combustion recovery process in the previously waterflooded Countess Upper Mannville "B" pool near Brooks, Alberta. The project, which is being operated by PanCanadian, was initiated in 1982 with a single combustion well surrounded by four producing wells. Production performance was encouraging and the

project was expanded in 1990 with the development of two additional combustion wells. Production data are now being gathered and analyzed for the expanded project.

AOSTRA contributes to the project by funding and operating a research program to support the field pilot activities. The supporting research program will continue through 1992. The program has included combustion tube tests, geological studies, emulsion treating studies, corrosion studies, combustion front mapping, a post combustion core well, a production PVT sampling well, numerical simulation modeling, core flow tests, and the development of the expansion-phase combustion wells. AOSTRA's costs to date for the $1.915 million program have been $1.655 million.

3.8 AOSTRA-Pfizer Profile Modification Studies

Pfizer Canada Inc. is the operator of a project with AOSTRA to field test the modification of injection profiles in waterflood injection wells by injecting a gelant slug into highly permeable thief zones. The demonstration of the effect of improved injection profiles in volumetric sweep and ultimate recovery is the goal of the project.

A field project has been initiated in the Pembina Cardium Unit No. 20 operated by Pembina Resources Limited. A gelant slug was injected into three waterflood injection wells in 1991 in the unit which is located in the Pembina Cardium pool, the largest conventional oil pool in Alberta. Post injection production data are now being gathered for analysis. AOSTRA's cost for the project is $256,741.

Negotiations have been initiated with other field operators to identify additional suitable candidate fields and to conduct further field tests using the gelant plugging technology.

3.9 AOSTRA-Vikor Joffre Viking CO_2 Miscible Flood

Vikor Resources Ltd. operated the Joffre Viking CO_2 miscible pilot project on behalf of AOSTRA and the unit participants in the project. The pilot tested the ability of a CO_2 miscible flood to recover tertiary oil from a thin, previously waterflooded and abandoned sandstone reservoir containing light high-gravity oil. The project, which was initiated in 1984, was located in central Alberta approximately 20 km northeast of Red Deer and was the first miscible CO_2 project to be conducted in Alberta.

The pilot, which consisted of two inverted five-spot patterns each covering 65 hectares, demonstrated the ability of CO_2 to improve the recovery of oil from the relatively thin lower Cretaceous sandstone reservoir. Incremental oil recovery amounted to 20% of the original oil in place for the tertiary project using CO_2 injection alternating with water injection for mobility control. A mobility control test using a foam surfactant was initiated in the original pilot area in 1988. The pilot project was completed on December 31, 1991. The net costs of the project for AOSTRA to date are $3.6 million.

The encouraging results led to the expansions of the project in 1985, 1988, and 1991. Further expansions of the project are being considered by the operator.

3.10 AOSTRA–Ulster Petroleums Retlaw Upper Mannville "V" Immiscible CO_2 Project

Ulster Petroleums Limited is operator of the first immiscible CO_2 project to be conducted in Canada. The project is located in the Retlaw Upper Mannville "V" Unit approximately 30 km northeast of Lethbridge.

The objective of this project is to evaluate the performance of a CO_2 immiscible flood in a medium-gravity water-sensitive reservoir. AOSTRA is acquiring operating and production data for analysis of the performance of the project. A preliminary analysis of the project performance was completed in 1991. The injection of CO_2 is now being followed by water injection. The project became commercial on January 1, 1991. AOSTRA funding for the project was $600,000.

4 COMMERCIAL DEVELOPMENT

4.1 Major Achievements

Implementation of AOSTRA's key priorities for this report year has resulted in significant progress towards the commercialization of new improved technologies developed by AOSTRA and its industry participants.

These achievements are due to AOSTRA's proactive approach and to the fact that industry now believes that commercialization of new promising technologies can be achieved with minimum environmental risks compared to existing commercial technologies. To achieve this level of confidence in the technology and its economic viability, the new approach

will be field demonstrated prior to commercial development on a larger scale.

AOSTRA's major achievements in oil sands technology commercialization can be summarized as follows:

- JAPEX Oil Sands Ltd. and CNPC Canada Ltd (China National Petroleum Corporation) joined AOSTRA's Underground Test Facility (UTF) as the eighth and ninth industry participants, respectively. This will contribute about $7.8 million towards the 1992 operation of the UTF.

- Six horizontal commercial-length wells were successfully drilled into the oil sands pay zone in the AOSTRA-Industry Underground Test Facility.

- AOSTRA commissioned a new 60-barrel-per-day AOSTRA Taciuk Process plant (ATP60) which will be used to field demonstrate the dry retorting pyrolysis of mined oil sands. The ATP produces a partially upgraded pipelineable oil product.

- AOSTRA licensed UMATAC Industrial Processes of Calgary to apply the AOSTRA Taciuk Process commercially for cleanup of oily waste materials worldwide. This technology has been commercially successful in the cleanup of U.S. Environmental Protection Agency SuperFund sites and is being considered for the cleanup of contaminated sites in Canada.

- AOSTRA continues to licence its Anti-Water-Coning (AWACT) technology to prevent water coning in oil production wells. Alberta Energy Co., co-developer of the technology with AOSTRA, continues to commercially apply the AWACT treatment process to several hundred of their wells. Six other oil companies are conducting field demonstrations to prove out the effect in their particular reservoirs.

- The ultramicrobacteria (UMB) technology is currently being field tested to demonstrate improved conventional oil production from watered-out wells. Continental Amelioration Research Environmentalists (CARE) Int'l Ltd. have been granted the North American licence to use the UMB technology for non-petroleum applications such as environmental containment of oil spills and prevention of leaching from hard rock mine tailings dumps. We are continuing negotiations with several interested parties to use the UMB technology in conventional oil field applications.

- AOSTRA has initiated task forces with industry cooperation for commercial development of Alberta oil sands leases using the Steam Assisted Gravity Drainage (SAGD) technology, currently being field demonstrated at the UTF project, and the AOSTRA Taciuk Process (ATP) for environmentally acceptable surface mining oil sands projects.

- Presentations of technical papers at important conferences, and displays at trade shows and conferences are other approaches used by AOSTRA to convince industry management of the commercial readiness of AOSTRA-owned technologies.

4.2 Underground Test Facility (UTF)

The Athabasca oil sands near Fort McMurray containing over one trillion barrels of bitumen have become accessible at almost all depths by using the technologies developed at AOSTRA's Underground Test Facility. These are the Shaft and Tunnel Access (SATAC) and Steam Assisted Gravity Drainage (SAGD) technologies utilizing commercial-length horizontal wells in the oil sands pay zone to recover bitumen in situ.

The UTF project was initiated by AOSTRA in 1982 with a series of design studies employing mine access to provide for effective testing of horizontal well in situ recovery processes. The positive results led to a commitment by AOSTRA to start construction of the UTF in 1984. Meanwhile, an industry steering committee consisting of 16 oil companies and AOSTRA also conducted a thorough evaluation. They confirmed that the commercial development of these previously inaccessible resources was technically and economically feasible by using the UTF technologies. During 1985, work continued on the mine construction and on the development of a custom drilling rig. This rig was designed to place commercial-length horizontal wells from the underground tunnel system.

In 1986, AOSTRA made a further commitment to test the SAGD process in Phase A of the UTF project. The mine access facilities were completed and the custom drilling rig was fabricated, field tested, and reassembled in the underground mine for drilling of the test wells.

In situ process testing was started in 1987 by AOSTRA and after initial success, six major oil companies joined

the project in 1988. Amoco, Chevron, Mobil, Petro-Canada, Shell, and Texaco became participants in the Phase A program. This entitled each of the six oil companies to an 8 1/3% share of the AOSTRA UTF lease if they continued to the end of the Phase B test program. Also CANMET, the Canada Centre for Mineral and Energy Technology of Energy, Mines and Resources Canada joined the test program.

Enhanced geotechnical work and a separate test of Chevron's proprietary HASDrive process were added to the program. The underground drilling program resulted in successful placing of eight horizontal wells with significant advances in horizontal well technology. The SAGD and HASDrive were started up successfully in the fall of 1987.

During the next two years both Phase A well tests proved to be unqualified successes. The SAGD process demonstrated a commercially viable combination of production rates, steam–oil ratios, and ultimate recoveries. Hence, in 1989, the Phase B SAGD test program was initiated by AOSTRA. Phase B is designed to confirm the necessary drilling accuracy and scale-up in performance using the commercial-length (600-m) wells.

Seven industry participants (Amoco, Chevron, Conoco, Esso, Mobil, Petro-Canada, and Shell) joined AOSTRA to start Phase B construction in the spring of 1990. In 1992, two new participants joined the project (Japex Oil Sands Ltd. and China National Petroleum Corporation). Currently there are nine industry participants which have the option to complete the Phase B program and each earn an 8 1/3% share of the UTF lease.

To date, all of the 550 m of tunnel have been driven in the limestone beneath the oil sands deposit and secured. The six 600-m horizontal wells have been successfully drilled and completed in the oil sands pay zone. The three well pairs are spaced 70 m apart and each well pair consists of a production well at the base of the oil sands and a steam injection well about 5 m above the production well.

The wells were steamed and produced in a warm-up phase from October 1991 to April 1992 using the smaller Phase A steam plant. The construction of the larger Phase B surface process facility

JAPEX delegation, pictured here with AOSTRA representatives, visited Alberta last fall to evaluate UTF. ***From left, front row:*** *Junichi Matsumoto, Minoru Fujita, William Yurko, Noboru Tezuka, Rick Luhning, Elma Spady;* ***back row:*** *Peter Mittal, Brad Anderson, Neil Edmunds, Cal Bohme, Ryohei Wakishima, Toshiyuki Hirata, Hideyuki Aoyama, Doug Komery, Yukio Kishigami, Kunihiko Kato, Kiyoyuki Sato.*

UTF Project Phase B Construction

is taking place during the summer of 1992 with start-up scheduled for the fall of 1992. Production is expected to reach 2000 bpd in early 1993. This will be a high-value, dry bitumen product from which the revenue will be used to offset the operating costs. Testing is scheduled to be completed by mid-1994.

4.3 UTF Commercial Development

The Steam Assisted Gravity Drainage (SAGD) process being optimized in the highly successful field demonstration test program at the UTF site is expected to form the basis of the next commercial bitumen recovery project in the Athabasca oil sands. This is the starting point for a study initiated recently by AOSTRA and its industry participants with the goal of developing plans for a future commercial oil sands operation.

A commercial project with a bitumen production capacity of 30,000 barrels per day (bpd) has been selected as the base case for this study. This is in keeping with the results of previous investigations which show that the supply cost of bitumen using SAGD technology becomes competitive with that of conventional oil when plant capacity reaches 20,000 to 40,000 bpd. This level of production would appear to be well suited to the size of the exploitable reserves in that portion of the AOSTRA lease being considered for initial commercialization.

Besides recommending optimal plant capacity, the study task force objectives include ensuring that plant design takes into account reservoir characteristics, the technology available, and environmental regulations; working out logistics and ensuring coordination with existing UTF operations; examining project economics and financing options; and considering the operatorship of the commercial project and the structure of the operating consortium (*i.e.*, single company or joint venture). Other key objectives will be identifying and evaluating marketing opportunities for the bitumen product.

One of the marketing options being explored as part of the study is pipelining the bitumen product to existing upgrading facilities at Suncor or Syncrude. Alternatively, the bitumen could be sent to a regional upgrader, or via Edmonton and the North American pipeline system to heavy oil markets in the United States.

A recommendation by the study task force on whether to proceed with a commercial project will hinge on the

CNPC Signing of UTF Participation Agreement; from left, front row: Gao Run Qing, CNPC; W.J. Yurko, AOSTRA; Wang Naiju, CNPC; R.W. Luhning, AOSTRA; back row: Li Jian Hou, Wang Jianshe, Liu Ping Nan, CNPC; C. Hsi, E.J. Wiggins, D.P Komery, AOSTRA.

project's potential for becoming the lowest-cost producer of bitumen, thereby offering a relatively attractive return on investment for industry. Improvements to the SAGD technology are also being evaluated. One such project is considering the application of SAGD technology to twin horizontal wells drilled from the ground surface.

AOSTRA and industry believe that there is good reason to be optimistic based on the favorable results achieved so far using the SAGD recovery process at the UTF project. The mid-1993 target for completing the major elements of this study will allow sufficient lead time for industry groups wishing to move ahead with a commercial project to prepare their 1994 budgets accordingly.

4.4 AOSTRA Taciuk Process Oil Sands Commercial Development

The AOSTRA Taciuk Process (ATP) is a thermal retorting process which produces a pipelineable coker-type 23°API distillate product and dry hydrocarbon-free tailings. This technology has undergone continuous development over the past 15 years. More than $20 million have been spent to date and over 15,000 tonnes of oil sands have been tested at the AOSTRA pilot plant facility in Calgary. Positive results from this development work have established the AOSTRA Taciuk Process as a prime technology for the commercialization of surface-mineable leases. AOSTRA's internal economic studies indicate that this technology can reduce the supply cost of synthetic crude oil by at least 20% when compared to current commercial technology options.

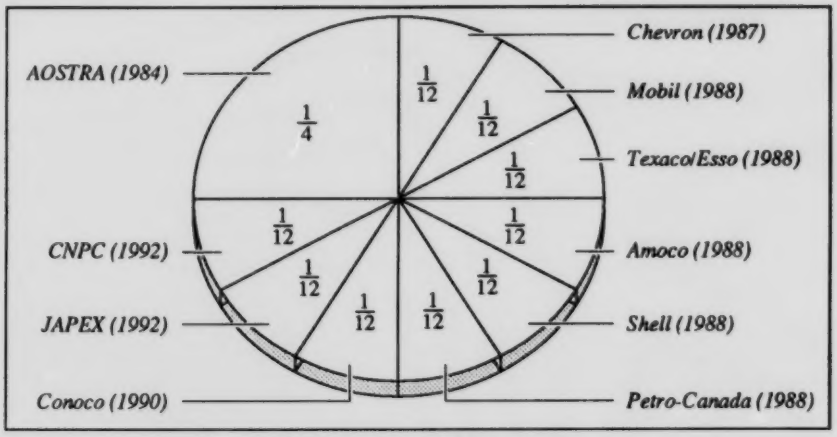
AOSTRA's positive view of the technology has been reinforced by the commercial development of the ATP in other areas such as oil shale and oily waste processing. These alternate-use commercial developments have provided technical and operational confirmation of the process and the mechanical reliability of the ATP. They have set the stage for implementing the technology in the role for which it was originally developed, that is, commercial development of Alberta's oil sands.

To initiate the commercialization phase for oil sands development, a new ATP plant, rated at 60 barrels per day (ATP60) was constructed in Calgary for AOSTRA by UMATAC Industrial Processes Ltd. Mounted on highway trailers, the self-contained plant can be transported to oil sands leases for demonstration purposes. Construction began in early 1991 and the plant was mechanically completed in March of 1992 at a cost of $4.5 million.

The ATP60 plant will serve as a focal point for a planned cooperative industry/AOSTRA task force for the purpose of evaluating the commercial potential of the ATP technology. The task force program will enable industry to better understand the technology and will provide AOSTRA with valuable industry input. If successful, the task force program will set the stage for the development of a semicommercial 5000-barrel-per-day ATP demonstration plant (ATP5000). The task force is scheduled to be established in August of 1992.

4.5 ATP Commercial Application in Oily Waste

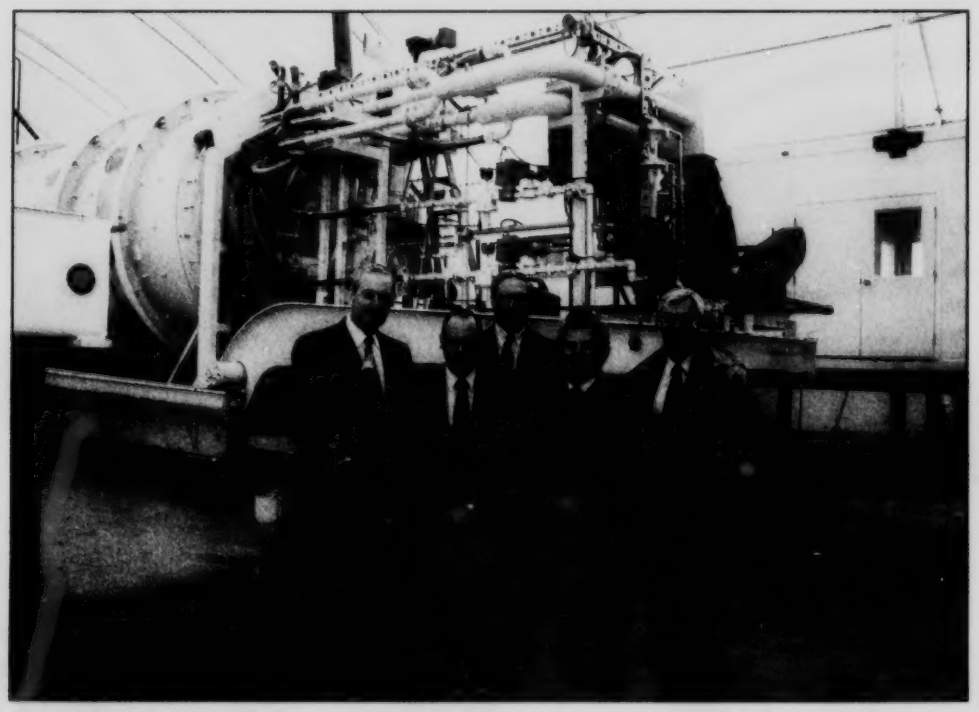
The application of ATP technology for the processing of hydrocarbon-bearing soil materials has proven to be a commercial success. The licence granted in 1988 to the developers of the technology, UMATAC Industrial Processes of Alberta, a division of UMA Engineering Ltd., was modified in early 1992. In consideration of the intense worldwide interest being generated in the use of this technology for waste processing, AOSTRA extended the original North American licence for the processing of hydrocarbon-bearing soils to a worldwide licence for all waste materials processing.



Participation in UTF project

Royalties generated as a result of this exclusive licence will continue to be paid to AOSTRA by UMATAC and all of its sublicensees for the commercial processing of waste materials.

SoilTech Inc. of Porter, Indiana, a subsidiary of UMATAC, and Canonie Environmental Services Corp. of Porter, Indiana, were sublicensed to use the ATP technology commercially for remediation of hydrocarbon-contaminated soil materials in the United States.



***From left:** A.R. Pasini, R. Savage (UMA); D.P. Komery, W.J. Yurko, R.W. Luhning (AOSTRA) with the 60-barrel-per-day ATP oil sands processing plant*

SoilTech purchased the first commercial ATP plant for soil remediation from UMATAC in 1988 for $4.5 million (Canadian). The 240-tonne-per-day transportable ATP plant was constructed by UMATAC in Alberta in 1989 and was successfully performance tested at AOSTRA's Calgary pilot plant site. The ATP plant was then transported to Wide Beach near Buffalo, NY, where it completed the cleanup of about 38,000 tonnes of oil-contaminated soils containing polychlorinated biphenyls (PCBs).

During the on-site operations, the commercial ATP system was tested under the U.S. Environmental

Signing of licence agreement for applications of the ATP in oily waste cleanup worldwide; from left: W. Taciuk, L.R. Turner, A.R. Pasini, R.H. Savage, W.J. Yurko, D.P. Komery, R.W. Luhning

Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) program. The SITE test results were very favorable and satisfied the guidelines for process testing to obtain a permit under the Toxic Substances Control Act (TSCA).

Upon completion of the Wide Beach job, the ATP was cleaned and decontaminated before being transported to the next remediation project at Waukegan Harbor, Illinois.

Operations at the Waukegan Harbor Superfund project began in January 1992. As of March 1992, the ATP system had maintained an average feed rate of nearly 10 tonnes per hour, and had a net plant availability of over 90%. At present, approximately half of the estimated 18,000 tonnes of PCB-contaminated harbor silts have been successfully processed.

In Canada, UMATAC and ADSUMA, the Canadian company formed by UMATAC and ADS Engineering of Montreal, continued to seek and identify other commercial opportunities for the ATP. Proposals have been prepared and submitted to:

- Alberta Environment's "Action on Waste" Program for disposal treatment of used rubber tires.
- Ontario Environment, for a demonstration plant on wastes from sites in the Toronto area.
- Numerous major oil and utility companies and other provincial agencies, for the cleanup of oil- and PCB-contaminated soils and sludges, drilling muds and cuttings, refinery wastes, coal tar residue wastes, and wood preservatives.

Through the efforts of AOSTRA and UMATAC, much international interest has developed in the use of ATP technology for hydrocarbon recovery from contaminated soils. China, Germany, Japan, Russia, and countries in the Persian Gulf area have indicated interest.

4.6 ATP Oil Shales Commercial Development

Southern Pacific Petroleum (SPP) and Central Pacific Minerals N.L. (CPM) of Australia investigated more than 15 different technologies from five countries for the processing of the rich oil shale deposit in Queensland, Australia. They found that the ATP technology was the most technically and economically viable process for extraction of oil from oil shales.

In 1987, more than 1600 tonnes of Australian (Stuart) oil shales were processed in AOSTRA's 105-tonne-per-day (tpd) fixed pilot in Calgary. Due to highly successful test results, scale-up testing, and technical and economic assessments during 1988 and 1989, SPP/CPM have undertaken to work towards construction of a 6000-tonne-per-day oil shale processing demonstration plant at Queensland, Australia. Construction is planned to start as soon as the operators secure government tax and royalty agreements and third-party project financing. SPP/CPM are also negotiating with an international engineering, procurement, and construction contractor to construct the semicommercial plant. This demonstration project will produce

more than 4400 barrels per day (bpd) of shale oil products. SPP/CPM plan to increase the project capacity to 60,000 bpd synthetic crude in stages, using scaled-up multiples of the AOSTRA Taciuk Processor.

AOSTRA has licensed SPP/CPM to process oil shales in Australia contingent upon SPP/CPM constructing and operating the ATP demonstration project. AOSTRA's formal agreement with SPP/CPM ensures that the prime engineering of the ATP systems and construction of the key components of the processing plant will be conducted in Alberta by the Calgary firm UMATAC Industrial Processes, which has developed the ATP technology with AOSTRA over the past 15 years. The agreement also allows AOSTRA's participation in the performance testing of the demonstration plant and ownership of all new processing, mechanical, and scale-up technologies developed during the operation of this plant. The processing of oil shales is very similar to that of oil sands; hence, this will provide AOSTRA with new improved technologies which can be incorporated into large ATP processing plants for Alberta oil sands applications.

4.7 Anti-Water-Coning Technology (AWACT)

This technology was developed in conjunction with Alberta Energy Company (AEC) and tested in their Suffield Heavy Oil Project (SHOP) in east central Alberta. The goal was to provide remedial treatment for wells that were producing more water and less heavy oil than is economically viable. The technology developed involves injecting a hydrocarbon-based liquid in a watered-out well, followed by the injection of natural gas. This treatment tends to block off the water resulting in more oil production, and hence longer well life and greater reservoir oil recovery.

The AWACT treatment program for AEC's South Jenner wells has been underway since late 1990. Oil production increases from the nine AEC wells treated thus far have been good.

Eight AWACT treatments have now been conducted outside of the AEC SHOP area. AWACT technology licensing agreements have been executed with Petro-Canada (Bellshill Lake), PanCanadian (North Bodo), and Koch Exploration (Chin Coulee). Cost-sharing field tests and technology use licensing are currently in progress with Amoco, Suncor, Renaissance, and Maxon.

An in-house market survey of potential applications was conducted and a business development plan was prepared.

4.8 Technology Sales and Licensing

The Technology Sales marketing group is responsible for the commercialization of AOSTRA research results which cover all the scientific and engineering fields related to advanced oil recovery technologies. The highlight of the 1991/92 year was the execution of two Underground Test Facility participation agreements with a combined value of over $13 million.

Displays at trade shows, technical presentations at conferences, and advertising made a significant impact on the awareness of technologies available from AOSTRA.

The most important technology sales achievement in 1991/92 was the growth in the membership roster of the Underground Test Facility with the addition of Japex Oil Sands Ltd. and the China National Petroleum Corporation (CNPC).

Most of the work during the past year has involved activities related to the commercialization of technologies in the following areas:

- Underground Test Facility industry participation sales
- AOSTRA Taciuk Processor commercialization
- Technology sales and services
- Ultramicrobacteria (UMB) technology licensing

Underground Test Facility Participation Sales

Due to the continued success of the UTF project, the membership roster grew with the addition of Japex Oil Sands Ltd. and China National Petroleum Corporation (CNPC). Representation is summarized as follows:

- CANMET
- Amoco Canada Petroleum Co.
- Esso Resources Canada Ltd.
- Chevron Canada Resources
- Shell Canada Ltd.
- Mobil Oil Canada
- Conoco Canada Ltd.
- Petro-Canada Inc.
- Japex Oil Sands Ltd.
- CNPC Canada Ltd

Each of the above, except CANMET, own an 8 1/3% interest. This represents 75% of the project. AOSTRA's share is currently 25%.

Interest in the UTF continues and there is potential for growth in membership from other companies.

AOSTRA Taciuk Processor (ATP) Commercialization

A 60-barrel-per-day (ATP60) plant has been built for AOSTRA and is ready for oil sands testing. Considerable effort has gone into advertising and promoting the ATP to realize its ultimate full commercialization. Opportunities that may be created for the ATP as a result of the expiration of surface mineable second-term leases are being pursued. Twelve companies own about 80% of recoverable oil sands reserves in second-term leases. All of these companies, and many others, have been contacted and asked to participate in a joint AOSTRA-industry task force to assist in the planning and evaluation of a potential demonstration oil sands test.

Technology Sales and Services

The major technology trade between Japan Canada Oil Sands (JACOS) and AOSTRA in 1990 involved trading the AOSTRA GLISP injection and production data, accumulated during the GLISP seismic monitoring program, for the JACOS integrated geophysical study of the GLISP project. The trade enabled JAPEX Geoscience Institute Inc. of Tokyo to further evaluate the concept of seismic monitoring to trace the horizontal extent of thermal fronts in the subsurface.

The technology sales group coordinated or participated in the following trade shows:

- National Petroleum Show, June 1992, Calgary
- Haztech Canada (Western) Trade Show, October 1991, Calgary
- UTF poster display at Canadian Association of Petroleum Landmen (CAPL), 13TH Annual Conference, Whistler, B.C., September, 1991
- UTF poster display at 5TH UNITAR International Conference, Venezuela, August 1991
- 5TH UNITAR International Conference, Venezuela, August 1991, Trade Show
- Polmet 3RD International Environmental Conference, December 1991, Hong Kong
- DEA 44 Horizontal Drilling Symposium, UTF Poster Display, June 1991, Calgary
- Canadian Oil and Gas Show, June 1991, Edmonton

As in previous years, the technology sales group organized tours to various AOSTRA pilot facilities. As well, many papers were prepared and presented at various technical conferences.

Ultramicrobacteria (UMB) Technology Licensing

Through conference presentations and AOSTRA staff contacts, two licences are in the process of being issued to utilize this UMB technology in the applications listed below. One application of this technology will lead to increased oil recovery from borderline or shut-in wells.

- *Continental Amelioration Research Environmentalist (CARE).* For non-petroleum application of AOSTRA-owned UMB technology in areas such as seepage prevention for dam sites, irrigation, sewage works, mine tailings ponds, and contaminated sites.
- *Chambers Engineering, Kiseki, and CARE.* For commercial application as an anti-water-coning control method in oil field production.

4.9 AOSTRA-Syncrude Study for Mining/Extraction Comparisons With UTF SAGD Technology

The two commercial mining oil sands projects in Alberta are currently examining improved technologies to recover the bitumen more efficiently as the bitumen "ore" becomes more distant from the existing extraction and processing plants. The overburden removal costs play an increasingly significant role in determining the economic viability of mining the deeper oil sands.

One method of accessing these deeper reserves is to use the Steam Assisted Gravity Drainage (SAGD) technology developed at AOSTRA's Underground Test Facility. This approach would enable access to the bitumen in the oil sands beneath the existing tailings ponds without having to relocate the ponds; it would also permit access to other deeper reserves within the existing mining lease.

In 1991, AOSTRA and Syncrude began a study to evaluate the technical and economic viability of using SAGD technology to recover bitumen from the deeper areas of the existing surface mining lease in the Athabasca oil sands. Recovery of bitumen from deposits beneath the existing tailings ponds was also evaluated.

The study results showed that it was technically feasible to apply the SAGD technology to mining leases with as little as 30 m of overburden.

It was concluded that substantial savings in bitumen production costs could be achieved at commercial-scale production rates, using the AOSTRA SAGD process. This could be applied to both conventional mining leases and also to those reserves under existing tailings ponds.

A report on the study has been issued and is available from the AOSTRA technology sales group.

4.10 AOSTRA-Suncor Study to Compare Conventional Mining and SAGD Technology

Suncor has an early requirement to establish additional bitumen reserves from its leases in the Fort McMurray area in order to maintain current production levels at its commercial project. The company is currently considering improved mining and extraction methods but is also interested in other bitumen production technologies.

In 1991, a study was initiated to evaluate the technical and economic feasibility of the UTF SAGD technology and compare it with Suncor's latest mining and extraction technology. Preliminary results indicate that substantial cost reduction could be achieved by applying the SAGD technology on two of Suncor's oil sands leases in the Fort McMurray area. The study is continuing.

4.11 Comparative Economic Evaluation of In Situ and Mining Options For Commercial Oil Sands Development

Certain technologies are more applicable to deep in situ bitumen reserves and others to shallow bitumen reserves. Within each of the above major categories, specific technologies need to be technically and economically analyzed for the best application.

In order to provide AOSTRA with a comparison of the different applicable technologies, an in-house study has been initiated. The objective is to conduct an in-depth comparative analysis of the various mining, in situ, and enhanced oil recovery options. Preliminary results indicate that the Underground Test Facility SAGD technology and the AOSTRA Taciuk Process technology have an economic advantage over other alternatives for oil sands.

4.12 Atomic Energy of Canada Study on Comparison of Fuel Sources For Commercial Development of Oil Sands Leases

Depending on the recovery process used, the energy required to produce a unit of bitumen from oil sands is equivalent to 5–20% of the energy in the bitumen produced. This represents an important demand on natural gas, a premium fuel for other uses. AOSTRA is therefore supporting a study into the potential for utilizing nuclear energy to generate the steam, electricity, and hydrogen required for oil sands processing. AECL (Atomic Energy Canada Limited) and TransAlta are also participating in this study. Other potential participants are Alberta Power, SaskPower, and members of the oil production industry.

Preliminary indications are that natural gas is still the most economically advantageous source of energy. Nuclear power and coal could become economically attractive if the cost of natural gas were to increase to over $2 per gigajoule.

5 ENGINEERING AND TECHNOLOGY DEVELOPMENT

5.1 Amoco High-Pressure Air Injection Experiments

AOSTRA and eight other participants are supporting the second year of a project being conducted by Amoco Production Company to evaluate recovery from light oil reservoirs with high-pressure air injection. Accelerating rate calorimeter tests on nine samples and two high-pressure combustion tube tests were completed in the first year. AOSTRA's cost for the first phase of the study was $25,000 U.S.

5.2 Amoco WAG Ratio Study

Amoco Production Company completed a one-year multiclient laboratory coreflood study to develop a better understanding of the effect of water alternating gas (WAG) ratios on the initiation and propagation of viscous instabilities in oil wet cores at tertiary conditions in December 1991. AOSTRA and seven other participants funded the one-year project. AOSTRA's cost was $12,500 U.S.

5.3 AOSTRA/Industry Thermal Well Pumping Committee

The committee, consisting of AOSTRA, oil companies, and pump manufacturers, formed in 1989 to improve the life and performance of downhole pumps in thermal operations, is measuring and analyzing pressure drops across standard sucker rod valves and investigating other factors affecting

pump efficiency. A novel valve has been designed and developed by the committee for improving sand handling capability of rod insert pumps. The effect of pump angle on pump efficiency, important for horizontal well applications, is the current thrust of research being conducted at the Alberta Research Council for the committee.

5.4 AOSTRA Peace River Task Force

AOSTRA initiated a task force with four industry participants to evaluate the development potential of the Peace River oil sands reserve area. Although it was concluded that reserve lands had sufficient potential to warrant additional seismic work and possibly delineation drilling, the additional work was deferred pending more favorable economic conditions. Expenditures for this project totalled $56,000.

5.5 CH2M Hill Co-Generation

A multiclient study was initiated in 1991 by CH2M Hill to evaluate the potential of cogenerating electricity and steam in heavy oil production facilities. The design and costs associated with 10 cases covering various sizes of application were completed and economic analyses are in progress. Participants in the study are AOSTRA, SaskPower, SaskOil, Alberta Power, Sceptre Resources, and CANMET. AOSTRA's share of the $130,000 study is $50,000.

5.6 Golder Associates Hydraulic Fracture Propagation Study

A study to enhance the current understanding of how hydraulic fractures form and propagate within unconsolidated oil sand reservoirs was initiated by Golder Associates in 1990 and has completed two one-year phases. A total of 13 fracture tests in a highly instrumented large-scale laboratory physical model have been conducted to date and analyzed by numerical methods and with the nuclear magnetic resonance (NMR) imaging equipment at PRI. AOSTRA, industry participants (four in year one and three in year two), and CANMET support the program costing $210,000 to date. AOSTRA's share of the cost has been $70,000.

5.7 Hycal Multiclient Miscibility Study

A multiclient study to improve current miscibility tests and mechanism understanding was initiated by Hycal in March 1991. The study will provide a database for about 20 oils, an improved equation-of-state model, research into the rising bubble apparatus for miscibility testing, and tests of pressure-composition to analyze critical point changes in multicontact operations. Total cost of the 15-month project is $210,000. AOSTRA's cost will be $30,000.

5.8 In Situ Engineering Support Program

A program providing funding for in situ engineering studies aimed at developing an understanding of various new technologies and supporting efforts to develop technology and market field applications was established in 1987. Achievements in 1991/92 included:

- Geomechanics support of fracture modeling and applications evaluations.
- Authorship of a minifracture test interpretation and procedures manual.
- Development of a gas steam application concept for improved steam/oil ratio.
- Ultramicrobacteria technology development.

Expenditures in this program totalled $54,085 in 1991/92.

5.9 In Situ Site Studies Program

This program funds geological and other studies supporting AOSTRA projects and potential projects. Activities during 1991/92 included:

- Preserved core from the completed AOSTRA-funded Husky Kearl Lake project was acquired and stored for distribution to research groups and other parties.
- Analytical computer models developed by the Maurer DEA-44 horizontal well project were tested and used to predict well performance for horizontal well projects in which AOSTRA participated.
- A pressure buildup test conducted on the Beau Twining horizontal well was analyzed using the Servipetrol model earlier developed with AOSTRA funding.
- Engineering support was provided in designing and conducting AWACT (anti-water-coning) field tests.

Expenditures in this program during 1991/92 totalled $54,700.

5.10 In Situ Strategic Enhanced Recovery Program

Enhanced oil recovery technology development support is provided by this program. Activities during 1991/92 consisted of testing the potential of reservoir plugging using surfactant-metabolizing ultramicrobacteria. The preliminary testing was conducted at the Petroleum Recovery Institute at a cost of $5000.

5.11 Maurer DEA-44 Horizontal Well Technology

Maurer Engineering are operating the DEA-44 multiclient consortium formed to collect, evaluate, and develop horizontal well drilling, completion, and production technology. Phase 1, completed in November 1990, developed a strong technical base in the form of technical reports, case studies, and analytical models. Phase II, expected to be completed in November 1992, is extending this technology further and is focusing on completion and operation of horizontal wells. The cost of AOSTRA's participation was $35,000 U.S. in Phase 1 and is $35,000 U.S. in Phase II.

5.12 Mobil Geomechanical Study

A joint AOSTRA-Mobil study to measure the compressibility and other geomechanical parameters and to study the acoustic behavior of heavy oil sands under thermally induced stresses was initiated in 1989. Equipment to conduct core testing was constructed and successfully calibrated at the University of Alberta, and testing on one Mobil Iron River oil sands core has been conducted. Analysis of the test results in relation to seismic responses to heat and pressure observed on 3-D monitor and sonic logs in the Cold Lake area is underway. The total program, the majority of which was in the form of a grant to the University of Alberta, cost $174,000 of which AOSTRA's share was $87,000.

5.13 Norwest Coalbed Methane Study

Norwest conducted a preliminary study to examine the potential for producing methane from coal for upgrading heavy oil and for use as fuel for steam generation. It was concluded that further assessment is warranted in the area south of Battle River to support Lloydminster heavy oil operations. The study was funded by AOSTRA at a total cost of $12,050.

5.14 PRI Fines and Pyrobitumen Study

A multiclient study supported by AOSTRA and eight other participants and conducted by PRI was completed in October 1991. The project studied the significance of pyrobitumen and fines in Alberta Devonian carbonate reservoirs and their effects on enhanced oil recovery. Further research on this topic is being considered in other multiclient work at the Petroleum Recovery Institute dealing with productivity improvement. Project cost of $104,000 was shared by AOSTRA and eight industry participants. AOSTRA's cost totalled $40,000.

5.15 Petrolphysics Inc. Jet Drilling Feasibility Study

AOSTRA conducted a feasibility study into the current status and merits of the water jet drilling technique and directional guidance system in 1991. The study confirmed the potential of the concept and identified aspects needing development. A consortium approach to developing and demonstrating the jet drilling and directional guidance system was recommended. AOSTRA's cost for the study was $30,000.

5.16 Shell Bitumen Conversion Project

A joint project to analyze the aquathermolysis effects of various metal ions on the reduction of viscosity of Peace River oils was initiated by AOSTRA and Shell in 1990. The work, conducted by the Alberta Sulphur Research Laboratory in Calgary, was a follow-up of earlier work in the University Access Program. Autoclave tests at three temperatures and with a number of steam additives were conducted. Oil viscosities and other parameters were compared to those obtained without additives. The project was completed at a cost of $82,000; AOSTRA's share was $41,000.

5.17 Simons Consulting Services Anti-Water-Coning Project

A joint AOSTRA–Simons Consulting Services project to test a novel concept to reduce water coning in oil wells was initiated in 1988. Engineering design studies were conducted during 1988 and 1989 and a watered-out and abandoned Zama Keg River oil well (10-22-114-5 W6M) was acquired for the test in 1991. The well was re-entered, completed, and equipped in December 1991, and testing commenced in January 1992. Test results to date are inconclusive due to mechanical

problems; however, options for further testing are under consideration. AOSTRA's share of costs for the project was $501,261.

5.18 Simtech Oil Sands Fracturing Study

Geomechanical stress-strain finite element models for oil sands fracturing have been developed during three phases conducted by Simtech during the period 1985 to 1992. The development and validation of the models was actively supported and funded by AOSTRA, other industry participants, and CANMET. The final product from the project is a comprehensive modeling system, SIMTECH-TARSIM. TARSIM has been coupled to a number of reservoir simulators including CMG-STARS, SSI-THERM, and SIMTECH-DRS. AOSTRA's cost totals $44,360 for the three phases.

6 PRODUCED WATER RECYCLING PROGRAM

Since the late 1970s, AOSTRA has been actively involved in research dealing with the water which is co-produced with bitumen and heavy oil from in situ recovery operations. Because of a limited supply of fresh water, it is desirable to recycle any water that may be recovered, rather than dispose of it completely as production waste. The recycling of produced water to meet steam generation requirements offers two significant environmental advantages; it reduces the consumption of fresh water resources, as well as reducing the volume of wastewater requiring deep well disposal.

Produced water contains several impurities which must be removed if the water is to be reused as feed to a steam generator. In addition, the quality of the water produced with the heavy oil at an in situ recovery operation varies widely from one geological formation to another within Alberta.

AOSTRA's participation in the area of produced water treatment is crucial to advancing the state of knowledge of this critical issue, as well as the development of technologies and methods which can be commercialized for use in operating facilities.

6.1 AOSTRA/WTC/ Industry Produced Water Treatment Project

With current commercial technology, a major limiting factor to reuse of the treated water can be the total dissolved solids (TDS) concentration. TDS must be less than about 8000 mg/L in the boiler feed water, otherwise scale formation problems due to deposition of salts may result. Steam injection and production from a salty formation can produce water which is immediately too high in TDS or which, through recycling, can eventually become too high. TDS removal can be achieved through processes such as electrodialysis, reverse osmosis, vapor compression evaporation, and freeze desalination. However, many of these technologies are currently not economically feasible.

In 1986, AOSTRA, Environment Canada, Amoco Canada Petroleum Company Ltd., Dome Petroleum Limited, Murphy Oil Company Ltd., PanCanadian Petroleum Limited, and Westmin Resources Limited initiated the first phase of a project to test treatment processes for the removal of TDS from produced waters.

In Phase I of this project, the efficiency and operating characteristics of a vapor compression evaporator (VCE) for TDS removal were tested. Pilot testing of the VCE at Murphy's Lindbergh thermal project commenced in 1987 and was completed in 1988. Results of the pilot test demonstrated that TDS removal by evaporation is technically achievable. However, pretreatment of the VCE feed would be necessary to stabilize the characteristics of the water. This rendered the treatment more expensive than originally anticipated.

The total project cost of Phase I was $875,000 with AOSTRA's share being $375,000. The technical reports for Phase I have been listed in AOSTRA's Catalogue of Technology and Services (1990/91 edition).

Based on the costs estimated for vapor compression evaporation developed in the Phase I report, as well as preliminary cost estimates for electrodialysis developed by Environment Canada, a Phase II program was proposed to assess the economic feasibility of using membrane technology. Although the VCE process evaluated in Phase I was technically the most advanced of all the TDS removal technologies, the fact that pretreatment was now considered necessary suggested that electrodialysis, while not proven to the same degree as VCE, may offer potential cost advantages. Consequently, the participants approved the second phase of the project to test electrodialysis as a process for TDS removal.

The cost of Part 1 of Phase II was $188,000 with AOSTRA's share being 50%, or $94,000. The cost of Part 2 of Phase II is projected to be $462,000, with AOSTRA's share being $231,000. The total Phase II costs to AOSTRA will be $325,000

Part 1 of Phase II testing was conducted at the Amoco pilot site near Elk Point, Alberta. This testing consisted of field tests of two specific cross-flow membrane filters (ultrafiltration and microfiltration) as pretreatment alternatives for suspended oil and solids removal. The microfiltration unit was selected for the Part 2 of Phase II. In addition, Part 1 of Phase II included laboratory testing of a bench-scale electrodialysis unit. The bench-scale tests proved to be reasonably successful and it was decided to proceed to a pilot-scale test program. A final report for Part 1 has been received and accepted.

Part 2 of Phase II is the pilot test program of the electrodialysis process. The pilot involves the use of the microfiltration (MF) cross-flow filter, to be run as a pretreatment to the electrodialysis (ED) unit. Both the MF and ED units have been set up at the Norcen Bodo site near Provost, Alberta. The process train has undergone debugging and commissioning procedures. Eight weeks of batch test runs of the two units together (8 h/day) have been conducted. Extended 24-h/day runs are now underway and are expected to last for about two months.

6.2 AOSTRA/Shell "Peace River Metal Loss and Scaling Research"

Shell's autoclave research program represents a fundamental approach to solving the problem of unacceptable corrosion, erosion/corrosion, and scaling of commercial steam generators running on treated produced water. The overall objective of the research is to develop a fundamental understanding of silica-related boiler scale chemistry and thereby identify various boiler feed water chemistries that do not result in erosion/corrosion problems. This information will, in turn, allow judgements to be made on the most effective, efficient, and economical produced water treatment processes.

The total budget of this current research program is $600,000 over three years, of which AOSTRA is contributing 50% or $300,000. The project commenced on January 1, 1990.

Shell Canada Limited has had an ongoing research initiative aimed at investigating potential water treating alternatives for incorporation in its Peace River complex expansion. The produced water at Peace River is characterized by its high alkalinity and high silica content.

In May 1986, Shell, together with Pecten Canada Limited and AOSTRA, commissioned the design of a produced water treatment pilot plant to investigate the feasibility of using high-silica produced water as steam generator feedwater. Areas of concern specific to steam generator operation were identified. These concerns include scaling (magnetite, acmite, hematite, *etc.*) in the radiant tubes and metal loss in the return elbows. These observations are consistent with recent industry experience. Shell does not feel confident in recycling water at the silica levels identified in the Peace River study, due to the potential for erosion/corrosion in the boiler tubes.

Following the decommissioning of the pilot plant, a preliminary autoclave research program was initiated by Shell in 1989 at its Calgary Research Center (CRC), in order to address these concerns related to silica and scaling. The results of research from the autoclave program to date have revealed many of the specific factors leading to metal loss and scaling, as well as a determination of the water chemistries that brought about these problems.

The current autoclave test program at CRC utilizes test specimens or "coupons" made of carbon steel measuring only 11 mm in diameter by 87 mm in length. The coupons are tested in a 3.8-L, 40-MPa autoclave. Such a system provides significant cost savings over testing at the pilot facility at Peace River.

By varying the make-up water chemistry and physical exposure conditions, (*i.e.*, flux and steam quality) the factors which influence corrosion and scaling processes can be determined. The test program will provide a more fundamental basis from which to begin selection of a produced water treatment technology as well as future design of steam generators.

7 SURFACE MINING/ EXTRACTION PROGRAM

7.1 AOSTRA Taciuk Process — Base Program

Since 1977, AOSTRA and UMATAC Industrial Processes, a division of UMA Engineering Ltd. (UMATAC), have participated in the development of the AOSTRA Taciuk Process (ATP), an AOSTRA-owned technology. The ATP is a thermal retorting or pyrolysis process developed for the simultaneous extraction and primary upgrading of bitumen in mined oil sands. Process operation occurs in a single horizontal vessel, which is subdivided into four distinct functional zones. The products from the process are cracked oil distillates, oil-free dry tailings, off-gas, and process waters.

To date, AOSTRA has provided funds in the amount of $20.5 million for the

ATP Base Program, which has successfully developed the ATP to a state of commercial readiness for use in oil sands. In addition to oil sands, the ability of the ATP to process a wide variety of hydrocarbon-bearing feedstocks has led to the parallel development of the process for the recovery of liquid hydrocarbons from oil shales and for the commercial treatment of oily wastes. The use of the ATP in these alternate applications is discussed in Section 4 of this Annual Report.

Each year AOSTRA and UMATAC establish an annual Base Program and corresponding budget. This program provides for

- the continuing development and improvement of the ATP technology;
- the testing of candidate feedstocks and the preparation of preliminary designs and cost estimates for ATP plants at the conceptual level;
- the retention and maintenance of AOSTRA's pilot plant facilities in Calgary, Alberta, and the project office.

The mechanical and structural design of the processor is an evolutionary process which incorporates the experience gained through the detailed engineering of Southern Pacific Petroleum's proposed 6000-tonne-per-day oil shale plant for Queensland, Australia, and the design modifications arising from the commercial operation and maintenance of the 10-tonne-per-hour oily waste treatment plant owned and operated by SoilTech, Inc. in the United States.

Under the Base Program, areas for process improvement have been identified and work initiated to assess the geotechnical and chemical characteristics of the oil sands tailings produced in the ATP, to evaluate use of lime injection into the combustion zone of the processor for sulphur capture, and to examine proposed process modifications to increase the yield of cracked oil product.

Continuing interest in the AOSTRA Taciuk Process has given rise to numerous test programs on candidate feeds from around the world, further emphasizing the growing commercial potential of the AOSTRA Taciuk Process. These programs vary in complexity depending on client requirements, but usually involve batch testing of the candidate feed, characterization of the products, and capital and operating cost estimates for preliminary commercial feasibility studies.

7.2 OSLO (Other Six Leases Operation) Borehole Mining

OSLO has been developing the technical features of a borehole hydraulic mining (BHM) process to extract bitumen from oil sands reservoirs located at depths between 100 and 300 m. OSLO leases contain about 17 billion barrels of bitumen in this depth range, which cannot be economically extracted by surface mining or in situ methods currently used successfully by industry. This technology involves drilling a borehole into the oil sands reservoir and hydraulically mining by means of a high pressure water-jet. The slurry produced from this process, would be compatible with the OSLO cold water extraction process.

AOSTRA, to date, has participated in four years of continuous development of the process. The first three years of the program involved preliminary jetting tests in the field and laboratory, geotechnical modeling, feasibility screening studies, testing of an extendible jetting arm, and the purchase and refurbishment of a borehole mining system. AOSTRA's share of the costs of the first three years of development was $1.4 million, approximately 50% of the total. The results of the first three years were sufficiently encouraging to justify proceeding with the next phase of the program.

The 1991 program (Year 4) was reduced in scope due to budget constraints. AOSTRA's contribution was limited to $150,000. No field or laboratory testing was conducted. The work focused on the development of a design basis memorandum (DBM) for a field demonstration pilot to be constructed and tested in 1992. The main elements of the DBM involved selecting the location of the field pilot, defining the borehole mining equipment requirements, defining the testing program, preparing definitive capital and operating cost estimates for the field demonstration program, and establishing the reclamation requirements.

The field program is scheduled to take place in the fall of 1992. AOSTRA has agreed to participate at a 50% contribution level. The $1.9 million program will involve mining a cavity at commercial target depths and collecting critical performance data in order to determine if the technology has merit for commercial development.

7.3 Canadian Oil Shale, Burning Rock Oil Co. Ltd.

AOSTRA and Burning Rock Oil Co. Ltd. have completed a project which evaluated the feasibility of using the AOSTRA Taciuk Process (ATP) for

extracting oil from the Pasquia Hills oil shale deposit in Saskatchewan.

The work focused on an area identified by Burning Rock Oil Co. Ltd. as having potential for economic viability which might provide an opportunity to demonstrate the use of the ATP technology in an oil shales application in Canada. AOSTRA funded the project at a cost of $60,000.

The work involved drilling five core holes for sample acquisition, batch testing at the AOSTRA Taciuk Process pilot plant in Calgary, and preliminary engineering and economic analysis of an integrated mining/ATP/hydrotreating facility.

The results from the core drilling highlighted the existence of a uniform zone of oil shale approximately 15 m thick, averaging 16 U.S. gallons/ton of shale oil. Based on this information, a feasibility study was conducted on a stand-alone 15,000-barrel-per-day integrated plant. The results of the study indicated that the project was not economical at current oil prices due to lower than expected oil content and the high cost of hydrotreating. Based on these results, AOSTRA has elected not to participate in any further work at this time.

8 UPGRADING PROGRAM

Upgrading of bitumen to synthetic crude oil continues to be the major cost factor in the production of oil from oil sands. The cost of synthetic crude oil may be reduced by using lower-cost feedstocks. Coprocessing of coal with bitumen is one option which AOSTRA and industry have investigated in the past year.

8.1 Coal–Heavy Oil Coprocessing Study

The addition of low-cost coal has the potential to lower feedstock costs but processing costs for coal are higher. Earlier studies had shown that the economics of coprocessing coal and bitumen were on a par with heavy oil upgrading at current coal costs and oil prices. As prices increase, the advantage for coprocessing increases. The specific justification for coprocessing would depend on factors such as location, integration, and technology.

In 1990, AOSTRA initiated a $200,000 jointly funded project with 12 participants to review the strategic factors which would influence the economics of a pioneering coprocessing venture. These factors included location, product marketing, technology, integration, and environmental regulations. This project was completed in 1991.

The best cases identified in the study were located near mine sites in the Edmonton area because of the developed infrastructure and availability of low-cost coal and byproduct hydrogen. Technology and plant size also influenced project economics. The major conclusion from the study is that coprocessing remains a future option. Significant increases in oil prices are required to justify the addition of coal in spite of its inherent lower cost.

8.2 CANMET Coprocessing Research Consortium

The previous study indicated that coal–heavy oil coprocessing was a technology that could lower costs and extend the resource base in the future as oil becomes more expensive. Large-scale demonstration projects and pioneering commercial ventures may not be justified at this time but there remains a justification for lower-cost, multiparticipant, more fundamental research and development. On this basis, AOSTRA is a participant in the CANMET Co-Processing Research Consortium.

The consortium is a three-year project with a cost to each participant of $150,000 per year. EMR CANMET matches the participant's contributions and the work is done at the Energy Research Laboratories (ERL) near Ottawa. Work programs and priorities are established by CANMET and the Consortium participants, AOSTRA, Amoco Canada Petroleum Company Ltd., and Rheinbraun, A.G.

In 1991, the work program focused on the operation of pilot plant and bench-scale reactors using feedstocks and process conditions of interest to the participants. The program also included a series of projects on product quality and the potential for refinery processing of coprocessing distillates as well as the utilization of residues. This project will continue throughout 1992.

8.3 Counterflow Reactor Test

AOSTRA and the Alberta Office of Coal Research and Technology funded half the cost of a $1.9-million test program with Canadian Energy Developments Inc. (CED) in Edmonton, to demonstrate the advantages of counterflow reactor technology. In most slurry phased hydrocracker reactors, the feedstocks and hydrogen enter the bottom of the reactor and the products exit at the top. With the high solids content in the reactor from coprocessing coal and heavy oil, there are potential advantages in feeding the coal and oil to the top of

the reactor, countercurrent to the upward hydrogen flow.

The test program on coprocessing Alberta feedstocks in a counterflow reactor was successfully completed by CED in 1991 at the Alberta Research Council's High-Pressure Test Facility at Nisku. The benefits demonstrated in the test program included improved operability, reduced preheating, and lower gas rates.

AOSTRA has declined an invitation to participate in a larger-scale demonstration of the CED technology in Germany because opportunities for early commercialization of coprocessing technology in Alberta were not evident.

8.4 CANMET Hydrocracking Process — Pitch Recycle Project

Pitch recycle has the potential of further improving the economics and reducing the environmental impact of high-conversion hydrocracking processes that use a "throw-away" additive or homogeneous catalyst. Based on this premise, AOSTRA and Petro-Canada each funded half the cost of a $850,000 project to quantify the benefits of pitch recycle in the Petro-Canada/CANMET Hydrocracking Process through pilot plant testing. The project was initiated in mid-1990 and was successfully completed in early 1992.

Pitch recycle was found to offer the following benefits:

- reduction in additive consumption;
- improvement in reactor productivity;
- achievement of conversions over 90%, economically.

A secondary objective also addressed was the modeling of continuous pitch recycle at steady-state conditions.

AOSTRA is currently doing an in-house comparative economic evaluation of the various processing options identified during the course of test work, to confirm the economic advantage of pitch recycle.

8.5 High-Recovery Hydrogen Separation

The hydrogen used in hydrocracking and hydrotreating is a major cost component in bitumen upgrading. Highquest Engineering Inc. has proposed a technology for hydrogen purification that has the potential to reduce hydrogen costs. Thermally Coupled Pressure Swing Adsorption (TCPSA) combines the pressure swings and temperature differences inherent with heat engines with differential adsorption on zeolite beds. This allows gas separation at high hydrogen recovery and high hydrogen purity while utilizing low-grade heat and mechanical energy to achieve high energy efficiency.

AOSTRA is providing $25,000 funding for a $250,000 project to design, build, and test a hydrogen separator using TCPSA. The Hydrogen Industry Council is the project sponsor.

8.6 CO_2 Balances in Upgrading

A study to quantify carbon dioxide emissions for various upgrading processes has been completed by RTM Engineering Ltd. The study concluded that the coking processes currently in commercial use are high CO_2 emitters due to the large amounts of carbon-rich coke burned for process heat. Hydrogen plants are also high CO_2 emission sources, but capture of CO_2 from hydrogen plants should be easier than from flue gases because of the higher CO_2 concentrations and pressures.

8.7 Other Activities

These activities were carried out or are being carried out to support ongoing projects within AOSTRA:

- *INTEVEP's HDH Process.* AOSTRA has initiated the comparative technical and economic evaluation of the HDH Process. The evaluation is based on results achieved in a test using a 0.3-bpd unit with Alberta feedstock. If the results of this evaluation are positive, further testing in a 10-bpd unit has been proposed.
- *AOSTRA Strategic Program — Development of $(HC)_3$ Process.* AOSTRA is providing ongoing technical support to the Alberta Research Council (ARC) in the development of the $(HC)_3$ process. $(HC)_3$ is a "third generation" upgrading technology being developed by AOSTRA and ARC. The process involves high-conversion hydrocracking using a homogeneous catalyst. It is expected that this process will provide a significant reduction in the cost of upgrading.

  To date, the base $(HC)_3$ process has been defined and demonstrated. Ongoing test work is continuing to further optimize the process.
- *Coal–Heavy Oil Coprocessing Study — Phase II.* AOSTRA was the contractor for the technology and economic package. The results were incorporated in the Coal

Heavy Oil Co-Processing Study referenced in Section 8.1, above. The task was to acquire process licensor packages, review them for consistency and correctness, define the cases, and develop capital and operating costs for each case and perform economic analyses.

- *CO_2 Disposal Study — Phase II.* AOSTRA is the contractor for the economics package to be incorporated in the CO_2 disposal study discussed in Section 9.2. The task involves generating the cost/benefit relationship, both on social and normal business bases, for recovery of CO_2 from defined sources for use in enhanced oil recovery projects or disposal into depleted gas reservoirs. This task is currently ongoing and is expected to be completed by October 1992.

- *Canadian Oil Shale, Burning Rock Oil Co. Ltd.* AOSTRA developed the cost estimates for a 15,000-BPCD stand-alone hydrotreating facility designed to produce a high-quality synthetic crude oil from shale oil obtained from the processing of Pasquia Hills, Saskatchewan oil shale using the AOSTRA Taciuk Process.

- *AOSTRA Taciuk Process (ATP).* AOSTRA developed cost estimates for a 76,000-BPCD stand-alone hydrotreating facility designed to process ATP distillates derived from Athabasca oil sands. This information is supplied to other companies to allow them to compare the overall ATP scheme to other schemes.

9 ENVIRONMENTAL ACTIVITIES

The advancement of relevant environmental research, as well as the compilation, assessment, and dissemination of pertinent technical information are part of the mandate of AOSTRA. Although not customarily identified as being directed solely at environmental issues, many of AOSTRA's projects deal with the development of technologies which offer potential for environmental benefits, if successfully applied commercially. For the most part, environmental benefits derived from technology development programs undertaken previously by AOSTRA have been supplemental to the broader goals of enhanced economics, resource utilization, and removal of technical roadblocks to resource development. AOSTRA has and continues to participate in projects which address:

- New processes for the extraction of bitumen from mined oil sands such as thermal retorting and solvent extraction processes, which generate dry or damp tailings and thus eliminate or reduce the need for tailings ponds.

- High-conversion bitumen upgrading processes which reduce the production of upgrader residues that are normally disposed of or stockpiled as waste byproducts.

- Produced water treatment processes which permit water for steam generation for in situ recovery to be recycled thereby ensuring supplies of boiler feedwater while at the same time reducing the demand for fresh water and the amount of contaminated water that is sent to deep disposal wells.

- The development of the AOSTRA Underground Test Facility to demonstrate the viability of shaft and tunnel access to bitumen reservoirs that are too deep for surface mining and too shallow for conventional in situ techniques involving high-pressure steam injection. Surface disturbance is minimized as a consequence of the underground access to the reservoir and no tailings wastes are produced.

- Research initiatives which address relevant environmental issues, such as tailings waste disposal, oily produced solids cleanup, reducing the toxicity of oil sands products, the reduction of gaseous emissions (such as SO_2, CO_2, and NO_x), and the monitoring and prediction of flue gas emissions.

In addition, AOSTRA has begun to take a more proactive approach in the Environmental area, by supporting projects which deal specifically with current environmental issues.

9.1 AOSTRA/Government/ Industry — Sludge Fundamentals Consortium

Currently, there are about 275 million cubic metres of fine tailings, or sludge in the tailings ponds of the oil sands mining plants located in northeast Alberta. The cleanup and reduction in the size of the tailings ponds that have resulted from use of the hot water process is a major environmental concern. The accumulation of the sludge in the tailings pond contributes to the ever-increasing volume of material which must be retained in the tailings ponds (since the fine solids settle very slowly or not at all). Methods are needed to dispose of this waste in an environmentally acceptable manner.

The private sector companies presently engaged in commercial mined oil sands projects, as well as AOSTRA and many institutional research organizations, have been searching for solutions to the tailings sludge problem independently of each other for many years. To date, tens of millions of dollars have been spent on this issue.

It became apparent to the various parties involved with sludge research that an economic process was not going to be easily found and, as a result, a coordinated approach was needed; hence the formation of the Sludge Fundamentals Consortium in 1989. The Consortium consists of research organizations, private sector companies, and government entities. The attractiveness of the Consortium approach lies in the bringing together of industry (with its practical, how to do it approach) together with government research institutes (with their more theoretical, investigative approach to problem solving). It is hoped that in this way, the Consortium will provide the supporting science and engineering theory that the companies require to produce the technology to solve the problem. In addition to AOSTRA, the members of the Sludge Fundamentals Consortium are the Alberta Department of Energy, the Alberta Research Council, Energy, Mines and Resources Canada (CANMET), the National Research Council, Environment Canada, Suncor, Inc., and Syncrude Canada Ltd.

The research projects initiated by the Consortium are focusing on the development of a better understanding of the physical, colloidal, chemical, and organic properties of the oil sands sludge which are thought to inhibit settling of suspended solids, and the methods by which these properties may be altered to promote solids settling.

To date approximately $5.4 million of in-house research costs have been contributed to the Consortium as work-in-kind by member organizations. In addition, AOSTRA, Alberta Energy, CANMET, and Environment Canada have contributed cash to a total value of $1,056,000 (AOSTRA's contribution has been $500,000 over three years). In summary, the Year 1 value of the Consortium effort was about $1.8 million, Year 2 value was about $2.5 million, and Year 3 value will be about $2.7 million.

The cash contributions are used to support the reimbursable cost component of certain projects performed by member organizations, and to contract third-party research from non-member groups such as universities and consultants.

The research work conducted under the Consortium during the first two years has largely been of a fundamental nature. It was necessary to compile data to fill specific technological gaps and to provide answers to outstanding questions on structure, stability, and properties. The key accomplishments of the Consortium during the first two years can be summarized as follows:

- All relevant information contained in industry files has been made available to the Consortium researchers. Much of this information has already been placed in the public domain through professional publications and various symposia. A special session of the 1991 CIM conference was held to discuss fine tailings issues.
- AOSTRA has established a comprehensive fine tailings library database containing currently available information. New contributions will be added as they become available.
- A consensus has been reached that the fine tails suspension is stabilized by poorly understood surface properties of submicron mineral particles consisting of clay minerals (kaolinite, illite, smectites) and amorphous iron oxides. The normal surface properties of these materials may be modified by adsorbed organic materials as well as pore fluid ionic species. Control of the surface properties by several methods is under active investigation.
- The resulting mineral-water suspension has many of the properties of gels. This is important in understanding the interaction relationships between coarse and fine solids. It has been noted that the formation of this gel can be suppressed in extraction processes which use sodium silicate for recovery enhancement, which suggests a potential alleviation opportunity.
- An open floc structure has been observed in mature fine tailings for the first time. When the mechanisms leading to the formation of this structure are understood, it may be possible to develop techniques to alter this structure to a denser configuration.
- The rheologic properties of fine tailings suspensions have been thoroughly investigated and found to be controllable by mechanical, chemical, and biochemical means. This leads to opportunities to increase entrapment in the tailings ponds, or to enhance the efficiency of mechanical separation technologies.
- A facies-dependent and process-dependent fine tailings volume prediction model will be developed

for the first time, thereby allowing improved estimates of future accumulation rates, as well as the determination of the impact of recently proposed alternate extraction technologies. The use of sodium hydroxide as a process aid has been investigated as a key input parameter. It has been determined that the ultimate volume of mature fine tailings is independent of the use of sodium hydroxide, although its use may retard the initial dewatering process.

- The primary toxic components of fine tailings have been identified as soluble organics by Consortium members. Considerable success has been demonstrated in degradation of these components in water overlying fine tailings deposits. Current work is focused on specific identification and control of these compounds within the fine tailings deposits.

In year 3, the mission statement of the Consortium has been enhanced to direct fundamental research at supporting the most promising mitigative methods (including dewatering concepts and toxicity issues).

9.2 AOSTRA/Government/ Industry CO_2 Disposal Study

Man-made emissions of carbon dioxide (CO_2), principally as a result of the combustion of fossil fuels, are acknowledged to be one of the major contributors to the atmospheric accumulations of greenhouse gases. It is recognized, generally, that there is no short-term alternative to the use of fossil fuels in our society. However, it may be feasible to collect and dispose of large accumulations of CO_2 in subterranean geological formations, or in certain hydrocarbon bearing reservoirs in which CO_2 injection could enhance the recovery of liquid hydrocarbons.

The CO_2 Disposal Project was originally conceived as a result of a proposal submitted to AOSTRA by the oil industry. During the evaluation process of the submission, it became clear that such an initiative was of interest to a number of parties, including the major oil companies, power companies, and support industries, as well as specific departments of both the provincial (Alberta and Saskatchewan) and federal governments.

Phase I was the scoping phase, aimed at determining the technical and economic feasibility of reducing the rate of growth of CO_2 emissions by collecting CO_2 from major sources and disposing of the collected gases where offsetting benefits may be obtained. Phase I was notable for, and successful, because of a very high level of participant involvement.

Phase I extended from November 1990 to April 1991 and was completed at a cost of approximately $30,000 or 60% of budget. Phase II began in June 1991 and has a budget of $600,000. AOSTRA and the Alberta government affiliates are providing $300,000 (AOSTRA is contributing $240,000); the other 50% of the cost ($300,000) is being shared equally by the remaining 24 participants from industry and other governments.

Phase II examines five different scenarios for the capture, purification, and transport of 50,000 tonnes per day of CO_2 captured in Alberta and Saskatchewan. Reflecting their relative contributions, two coal-based electrical generating stations have been included; Boundary Dam in Saskatchewan and Sundance in Alberta. The most common stationary source in Western Canada is the result of natural gas combustion; one such case will be examined. A sour natural gas processing plant case and a typical high-quality source, a hydrogen plant vent, will also be considered.

The work scope for Phase II is broken down into three work packages:

- Facilities
- Subsurface
- Economics

Todd, Chase Associates, were selected to model the EOR potential of a CO_2 miscible flood for the various fields selected. Reservoirs of various types containing both light and heavy oil will be screened and data collected. Simulations are being run on selected typical pools to predict incremental oil recovery and CO_2 utilization. The plan is to use a depleted natural gas reservoir to balance supply and demand. SNC/ Lavalin has been doing the preliminary engineering and cost estimating for the capture and purification facilities required at the various sources selected. AOSTRA will be providing the economic evaluation for each case in terms of cost of CO_2 supply to site and subsequent benefit, if any, realized. The EOR and facilities portions of the study are about 80% complete at this point and are beginning to feed the necessary information to AOSTRA in order to complete the economic evaluations.

A range of commercially available or demonstrated processes has been screened to establish cost-effective reliable technology for gas conditioning, CO_2 capture, and purification. Preliminary engineering and costing (±25% accuracy) of the various

components involved will form the basis of each case assessment. Costs will be determined for a dedicated pipeline network to distribute CO_2. These systems are being located and designed as part of the work scope.

A draft report for Phase II is expected for September 1992. The final report will include a publicly available summary document and one or more volumes of the confidential technical report.

9.3 AOSTRA In-House Environmental Initiatives

Underground Test Facility (UTF)

Although the UTF project currently utilizes an external consultant to act as its main environmental advisor, AOSTRA's Senior Environmental Advisor has been taking a more active role in the project in order to assist with many of the pressing issues involved in the start-up of the Phase B program.

Activities have included:

- Submission of the Clean Water and Clean Air licence applications.
- Assessment of and design of a plan to deal with solid wastes brought to the surface during drilling operations.
- Scoping and delineation of a produced water recycle test program, tentatively planned for the spring/summer of 1993.
- Participation on the issues committee for the planning of the UTF commercial operation

Environmental Audit Program

Environmental audit programs are conducted to identify and assess situations which may fail to meet regulatory requirements or corporate standards, or which represent unacceptable risks to the corporation, community, or public. They are constructive management tools, without any intent to penalize or reward individuals in the corporation.

A properly conducted auditing program of projects in which AOSTRA is either the operator or a participant will highlight AOSTRA's environmental commitment in the following manner:

- AOSTRA would ensure that it has addressed the environmental, health, and safety aspects of facilities in terms of its own responsibilities as a public corporation as well as a participant in the project.
- An assessment of the environmental situation if the process were to go to commercial scale (*i.e.*, commercial-scale level of waste emissions and other problems/issues not encountered at the pilot scale).
- A catalogue of all inputs/outputs on an operational basis at the pilot scale as well as the potential commercial scale.
- The audits may identify specific research and development opportunities for technologies which could have commercial application.

To date, AOSTRA has undertaken environmental audits of six facilities: Amoco GLISP, Norcen Bodo, Husky Kearl Lake, Bow Valley Industries, the Underground Test Facility, and UMATAC Industrial Processes. The main thrust of this initiative has been that the audits be conducted and used as an environmental management tool, and not just an examination of environmental compliance.

The most recently conducted audit of the UMATAC site in southeast Calgary has been extremely worthwhile in terms of identification of specific needs and improvements. UMATAC has undertaken to implement the recommendations of the audit.

Associations

AOSTRA continues to actively participate on the Canadian Heavy Oil Association (CHOA) Environmental Committee and has played an active role in the organization of committee meetings, luncheon seminars, and quarterly meetings.

AOSTRA is an associate member of the Canadian Petroleum Association (CPA) and actively participates on the Environmental Research Advisory Council (ERAC) of the CPA. AOSTRA made a presentation at THE CPA annual technology transfer meeting in March of 1992.

AOSTRA is also a member of the Alberta Special Waste Management Association. This membership allows AOSTRA to maintain a close link with current events in the waste management area, as well as providing another route for presenting the AOSTRA Taciuk Process as a waste processing technology alternative.

10 UNIVERSITY PROGRAMS

10.1 Lectureships

The AOSTRA Lectureship Program was introduced in late 1988. The program is intended to fund experts from Canada and abroad to travel to Alberta to present seminars or courses to industry and to the research community in areas relevant to AOSTRA's mandate. It has been highly successful

in meeting this objective and provides a means of teaching new skills needed to make Alberta's oil-producing industry more competitive.

In the current fiscal year, no funds were available to support this program, nevertheless, AOSTRA staff have assisted industry-run workshops.

10.2 Graduate Scholarships and Fellowships

AOSTRA's program for graduate scholarships and fellowships is the primary means of attracting Canada's brightest young graduates to do relevant research and to acquire skills needed by Alberta's petroleum industry. These awards are highly prized by students and their professors and respected by potential employers. Recipients are Canadians or landed immigrants residing in Alberta who must attend the University of Alberta, the University of Calgary, or the University of Lethbridge. They have demonstrated outstanding scholastic achievement, have done advanced research on problems of production and refining of bitumen and heavy oil, have published well, and have assigned useful patented processes to AOSTRA.

Since September 1990, no new awards were made under this program. Current award holders are those to whom commitments were made earlier and are identified in the following lists:

University of Alberta

Londry, K.	Ranger, M.*
Sanders, R.S.	Vekred, K.

University of Calgary

Blenkinsopp, S.*	Gomez, P.A.
Gupta, S.	Huang, H.
Kohse, B.F.	Taylor, S.K.

* Fellowships

The scholarships are $17,728 per year for a maximum period of two years and the research done normally leads to either a Masters or Doctoral degree. Fellowships are approximately $23,920 per year and are intended to assist postdoctoral scientists in furthering their training.

10.3 University Research Program

Universities provide a special environment for doing projects that test "radical" or highly innovative concepts. This is probably a direct result of the emphasis on creativity in universities and the availability of bright graduate students seeking advanced degrees. Their research projects yield much data and understanding that help develop needed technology. AOSTRA continues to support a wide range of these projects selected to assist the development of Alberta's oil sands and to transfer new technology and skilled young professionals to Alberta's petroleum industry. The projects are selected by a committee of leading scientists and engineers from Alberta's universities and petroleum industry.

The research is monitored by skilled professionals from AOSTRA and industry. The professors provide detailed technical reports of their progress and present a summary of their work at the Technical Review Meeting and Seminar held each October. At the Seminar in October 1991, the professors and their many graduate and postdoctoral students reported progress in 49 projects to an audience of more than 170 scientists and engineers from industry, corporations, and government agencies.

These industries and corporations participate financially in the program. Rapid transfer of useful technology to and from industry is assured by having these participants collaborate with the professors and their students in the research effort and by providing useful advice. Working together, students and professors apply their special skills to solving problems relevant to Alberta's petroleum industry. Since 1976, more than 540 graduate students and postdoctoral fellows supported by this program have developed the needed skills and obtained advanced degrees in the broad field of oil sands engineering and science. More than 80 professors now consult in this industry and do relevant research at Canadian universities.

The funding, $2.25 million this fiscal year, is less than that of previous years, but still remains a significant part of AOSTRA's effort. As of March 31, 1992, outstanding committed funds to this program amount to $1,925,444. For fiscal year 1992/93 and possibly 1993/94, no new commitments are planned for this program.

Brief descriptions of projects for this reporting period follow. These projects are ones completed in the previous fiscal year, but for which the final report was received in this fiscal year, projects completed in this fiscal year, and projects that will be completed in fiscal years 1992/93 or 1993/94.

1. Dr. A.K. Ambastha of the University of Alberta and a postdoctoral fellow are completing their analysis of data from in situ steaming pilots and from numerical models to determine whether results of pressure falloff tests may be used to estimate the heated volume of the reservoir and other parameters that affect the performance of steaming processes. Pressure falloff tests are inexpensive and rapidly done. Any useful results should provide the

operator a rapid means of controlling the steaming process. The response time for current numerical methods is much too long. Funds for this three-year project amount to $173,460.

2. Drs. L.A. Behie and W.Y. Svrcek and their students at the University of Calgary completed measurements of basic kinetic data of a novel upgrading process, ultrapyrolysis, that heats bitumen very rapidly to high temperatures. This process yields significant amounts of ethylene and butadiene, products that are important to Alberta's petrochemical industry. Funding of this work amounted to $203,000 over three years.

3. Drs. P.M. Boorman, R.A. Kydd, and T.S. Sorensen and their students at the University of Calgary developed novel catalysts that remove nitrogen from coker distillates. These catalysts contain small amounts of fluorine, phosphorus, arsenic, and antimony and are not poisoned by nitrogen as are conventional hydrotreating catalysts. Funding for this project amounted to $198,682 over four years. Total funding for this project and previous projects completed since 1976 by Dr. Boorman amounts to $698,713.

4. Drs. M. Brett and T. Etsell and Mr. C. Eastman of the University of Alberta are developing a small device that directly measures the concentration of sulphur dioxide in flue gas. Such an environmental monitoring device rapidly provides plant operators with important control data. Funding for this project is $203,144 over three years.

5. Dr. R.M. Butler, who holds the Distinguished Chair of Petroleum Engineering at the University of Calgary, and his many students completed theoretical and physical modeling studies of the steam assisted gravity drainage process that uses horizontal wells for the recovery of heavy oils and bitumen. Dr. Butler invented this process which has been tested already by Imperial Oil at Cold Lake, by AOSTRA at the Underground Test Facility near Fort McMurray, and by Sceptre Resources at Tangle Flags, Saskatchewan. The results indicate that this process may be the most economical one for producing heavy oil and bitumen and may even replace surface mining. Recognizing that many of Alberta's reservoirs contain swelling clays and consequently cannot be steamed, Dr. Butler and his students are now testing a new process that uses propane to recover oil. Funding for this three-year project is $235,418. Funding for previous studies amounts to $1,242,500.

6. Dr. P.M. Byrne and his students at the University of British Columbia are improving their computer program that models shear failure of oil sands. They work closely with staff solving important process-related problems at AOSTRA's Underground Test Facility near Fort McMurray. Funding for this project amounts to $57,000 over two years.

7. Dr. J.W. Costerton, who is the NSERC Professor of Biofilm Microbiology at the University of Calgary, and his many students are completing studies of a process that uses starved bacteria to selectively plug certain highly permeable zones of oil-producing reservoirs. Such zones are highly permeable ones or previously waterflooded zones in reservoirs. Plugging of such zones significantly improves the economy of recovering light and medium oils by the water-flooding process. It is worth noting that more than 50% of Alberta's light and medium oils are produced by waterflooding. Dr. Costerton's process is patented and licensed by AOSTRA to an Alberta company. He holds many other profitable patents ranging from a process to control corrosion of pipelines to important medical prostheses that resist infection. A total of $797,000 has been allotted to this and earlier projects over eight years.

8. Dr. P.J. Crickmore of the University of Alberta developed statistical methods that reliably predict the geology of a reservoir from data observed at sparsely located wells. The method, fractal analysis, was applied also to describing mechanisms of production of bitumen. The cost of this project was $77,080 over two years.

9. Dr. F.A.L. Dullien and his students at the University of Waterloo are completing experiments of his novel process using gas to displace residual oil from samples (cores) of an oil-bearing reservoir that had been waterflooded previously. An x-ray CAT scanner was used to determine production history, saturations, and relative permeabilities of small elements of these heterogeneous samples. Funds for this three-year project amounted to $239,160.

10. Dr. M.B. Dusseault and his many students at the University of Waterloo are completing work on the mechanics of the interactions between small particles of sand or clay. As part of this project he developed a numerical model that models fundamental processes of hydraulic fracturing and sand production. Since 1977, funding for this project and previous ones on dredging of oil sands, transporting of mine wastes, and geomechanics of hydraulic fracturing of oil sands formations amounts to $792,477.

11. Dr. N. Egiebor and his students at the University of Alberta are developing a process that removes silica from produced water in order that such

water may be reused to generate steam. His novel process, which uses calcium hydroaluminates (garnet), is non-toxic, clean, and likely more efficient than the conventional hot lime precipitation processes. Funding for this project is $102,500 over two years.

12. Dr. P.M. Fedorak of the University of Alberta is investigating the ability of certain fungi to remove metals from certain components (porphyrins) of bitumen or heavy oil. He isolated enzymes from these fungi and now finds them to be extremely active and highly selective in removing metals that foul or poison hydrocracking catalysts. If such enzymes can be attached to a porous substrate and remain active, then a commercially significant process can be developed. The cost of this three-year project and an earlier project with Dr. D.W.S. Westlake is $316,250.

13. Dr. M.R. Gray and his students at the University of Alberta are doing laboratory experiments to develop novel catalysts that are more resistant than existing catalysts to poisoning by the nitrogenous compounds contained in Alberta's bitumen. An important part of this project is the microscopic examination of the surfaces of spent catalysts and chemical analysis of the nitrogenous compounds thereon. Funding for this three-year project is $618,816 and for an earlier one on hydrocracking of bitumen amounts to $479,000.

14. Dr. R.E. Hayes of the University of Alberta is completing laboratory experiments to measure the dispersion of surfactants that have been added to a waterflood used to recover oil. He developed a high-speed computer program that models the experiments and is extrapolating the results to oil field experience. The cost of this two-year project is $58,232.

15. Dr. L.G. Hepler and his many graduate and undergraduate students at the University of Alberta completed their measurements of the kinetics and thermodynamics of oxidation of bitumen and obtained quantitative relationships useful in modeling in situ combustion processes. Funding for this two-year project and earlier ones on sludge treatment, gas dissolution in bitumen, and colloids found in tailings ponds amounted to $1,116,988 over 12 years.

16. Dr. I.E. Hutcheon of the University of Calgary analyzed fluids recovered from reservoirs that are being steamed or burned and developed a simple method of estimating the thermal history and progress of thermal processes. Such remote sensing is unique and is important for monitoring, control, and operation of such processes. In another project, begun in 1991, Dr. Hutcheon is studying mechanisms that affect the movement of silt and clay in pore spaces, a major problem for the oil industry since such movement can lead to a decrease in porosity and permeability of the reservoir. The cost of these projects and earlier ones completed over a nine-year period is $782,290.

17. Dr. E.R. Kanasewich and his many students at the University of Alberta are developing improved geophysical methods of seismic imaging and tomography to determine the oil and gas content of Alberta's reservoirs. Such remote sensing methods provide the operator with a three-dimensional view of the reservoir and more importantly those portions of the reservoir that are affected by steaming processes. The cost of this three-year project and earlier ones with Dr. E. Nyland is $1,225,872.

18. Dr. Y. Koga of the University of British Columbia developed a novel x-ray diffractometer that is capable of measuring with high angular resolution the slight scattering of x-rays by submicron sized particles. He is using this device to measure the amount and size of dilute suspensions of clay or flocs of clay in oil or produced water. Such measurement is unique and permits operators to monitor progress in removing clays and silt from produced fluids. The cost of this three-year project is $151,709.

19. Dr. W.G. Laidlaw of the University of Calgary developed a computer program to model the flow of foams in water through an oil-bearing sand. The model is closely related to laboratory experiments and shows the deterministically chaotic path taken by these fluids. He and his students are using this program to derive a more useful model of the mechanisms of fluid flow than the models currently used. Results show marked variations in the effect of different foams and operating procedures. The cost of this three-year project is $135,000.

20. Drs. S. Levine (Emeritus of Cambridge University) and B.D. Bowen, and a student of the University of British Columbia are using theory and experiment to identify the mechanisms by which fine particles and clays stabilize the emulsions that are found in oil sands tailings ponds. Funds for this seven-year project amount to $432,416.

21. Dr. F.J. Longstaffe is doing a detailed regional study of chemical changes (diagenesis) that occur naturally in sands, sandstones, and shales of the Clearwater Formation near Wolf Lake. He analyzed clays in samples of cores drilled from this formation and concluded that much surface water, perhaps from nearby lakes, penetrates a significant part of the formation, removes oil, and causes

swelling clays to be formed. On contact with fresh water or steam from a steaming process, these clays swell, plug the formation, and inhibit subsequent production of oil. Funds for this two-year project and an earlier related one are $123,817.

22. Dr. H. Machel and his students at the University of Alberta are studying the petrography and geochemistry of carbonate rocks and connate water obtained from the Grosmont and Hondo formations to identify and determine the effects of the major diagenetic processes. Connate water (ground water) dissolves portions of such carbonate rocks leaving large holes or vugs that eventually become filled with oil. These studies may provide a means of predicting what portions of these immense formations may produce bitumen easily. The cost of this four-year project is $232,000.

23. Dr. J. Masliyah and his many students at the University of Alberta completed his measurements of the rheology (viscosity and other flow properties) of emulsions containing bitumen, water, and suspended solids. They report a useful correlation of the experimental data. Their results show that washing a column of froth with water efficiently removes silts and suspended solids. This process is economical and may replace existing centrifuges. Now, Dr. Masliyah is developing a novel microwave process for removing water from produced bitumen The cost of these three-year and two-year projects amounts to $330,560.

24. Drs. R.G. Moore, J.D.M. Belgrave, and D.W. Bennion (emeritus), and a large team of students at the University of Calgary are doing experiments relevant to the in situ combustion process. They measure the kinetics of oxidation of bitumen in sand as a function of temperature and pressure. The scale of these key experiments is much larger than that of similar ones done earlier by Dr. Hepler and his students. Funding for this project is $303,624 over three years. Results of previous research by Professors Moore and Bennion led to development of the steam–oxygen combustion process that was tested so successfully by AOSTRA and British Petroleum at a field pilot near Marguerite Lake. This last process had the effect of reducing the cost of production by nearly a factor of two. Funding for Dr. Moore's previous projects on in situ combustion was $2,293,764 over 13 years.

25. Dr. K. Muehlenbachs and his students at the University of Alberta completed measurements of concentrations of isotopes of hydrogen and carbon in current commercial and experimental processes for upgrading bitumen. The data show details of effects of certain catalysts on "scrambling" of hydrogen and carbon moieties in these processes. Moreover, his experimental data may be interpreted to show little interaction of bitumen and coal when these two are coprocessed in a hydrocracker. Funding for this three-year project amounts to $203,000.

26. Dr. S.G. Pemberton and his team of many students at the University of Alberta are investigating the regional stratigraphy and depositional history of the North Athabasca oil sands deposit. Traces of fossil workings and of fossils provide good paleontological control of facies and permit his team to locate the ancient river channels that now are filled with rich oil-bearing sand. Also, his team studied data from more than 50,000 wells in Alberta and developed a new useful geological model for the province. Funds for these projects and previous related ones are $766,265.

27. Dr. D.Y. Peng and his students at the University of Saskatchewan are improving his equation of state that provides a thermodynamic description of continuous mixtures of the many thousands of hydrocarbon molecules found in bitumen. It is noteworthy that Dr. Peng and his colleague, Dr. D.B. Robinson, developed a well-known equation of state that is used widely by Alberta's petroleum industry. This "Peng–Robinson" equation of state is used throughout the world to predict efficiency and performance of distillation columns, pumps, and compressors used in refineries. In this work, Dr. Peng is providing additional capability to accurately predict the viscosity of hydrocarbon mixtures at various temperatures and pressures. Funds for this and an earlier project amount to $312,556 over four years.

28. Dr. V.R. Puttagunta at Lakehead University is continuing his work to determine the applicability of his simple correlation to predict the viscosity of bitumen–gas mixtures over a wide range of pressures and temperatures. The cost of this three-year project and an earlier two-year project is $86,512.

29. Dr. J.A. Rogers of the University of Alberta is completing his development of micro-encapsulation techniques to transport chemicals into a reservoir. Microcapsules of diameter less than one micron, similar to those used pharmaceutically, can be placed at depth in a reservoir to release chemicals over at least a 30-day period. By such means, many of Alberta's important gas producing wells may be kept clean of wax and asphalt. Also, nutrients to feed selected bacteria may be transported and released slowly and effectively deep in a reservoir. This one-year project is related to work described in item 7 above and costs $55,000.

30. Dr. D.R. Schmitt of the University of Alberta developed an ultrasonic device that he lowered in wellbores to measure deformations of these wellbores and nearby oil-bearing formations. In hydraulic fracturing experiments, he observed breakout of fluids from the wellbore. Results of observations taken while nearby wells were being steamed are being used now to determine how such processes affect in situ stresses and the likely directions of subsequent hydraulic fractures. Funds for this three-year project are $228,684.

31. Dr. J.D. Scott and his students at the University of Alberta are completing laboratory experiments to develop a complete constitutive mechanical model for oil sands of the Athabasca and Cold Lake deposits. Using triaxial cells, one of which is the largest of its type in the world, stresses are applied under conditions of pressure, temperature, and composition typical of steaming processes. Measured mechanical and fluid-flow properties of the above two deposits are significantly different and appropriate numerical models have been developed. As an extension of this work, Dr. Scott is doing laboratory experiments to evaluate volumetric deformations and permeability changes during cyclic steaming. The cost of this and previous projects amounts to $372,520 over five years.

32. Dr. O.P. Strausz of the University of Alberta is doing laboratory experiments to assess the use of steam-stripping on the formation of coke in a conventional delayed coker, the effect of colloidal catalysts on the selectivity of hydrocracking processes, and the effect of the thermal history of bitumen on its upgrading. This project and Dr. Strausz's preparation of a textbook on the chemistry of bitumen are the culmination of lengthy detailed analyses of the chemical composition of bitumen. Funding for this project is $280,000 over three years and for other projects over the preceding 13 years is $4,300,184.

33. Dr. E.L. Tollefson of the University of Calgary completed bench/pilot-scale experiments of a novel process to minimize bogging that can occur in a commercial fluidized-bed coker. Importantly, results of his experiments suggest that distillate yields from fluidized-bed cokers may be increased by as much as 5% through simple improvements to steam atomizers used to distribute bitumen in such cokers. Funds for this two-year project are $200,000. Funds for earlier work on desulphurization of coke and on sludge treatment are $578,370 over eight years.

34. Dr. H. Vaziri and his students at the Technical University of Nova Scotia have developed a computer program, ENHANS, that models stress and sloughing of sand near a well or near a mine shaft. He is improving this popular program to model further the flow of oil and water to the well and the markedly beneficial effects of producing some sand along with the oil. It is noteworthy that, with the recent development of suitably robust "Moineau" pumps, operators observe significant economical production, estimated to be as much as 40%, of cold bitumen from clayey oil sands. The cost of these two projects is $164,760 over three years.

35. Dr. J. Wan and his students at Queen's University completed the development of a novel reactor for thermally cracking distillates. The reactor contains small stationary elements of a metal catalyst that are strongly heated by microwave energy. In such a reactor, unusual chemical reactions are possible. Patents for the reactor and processes for synthesis, for example, of methanol from natural gas have been assigned to AOSTRA and are licensed to industry. Major petro-chemical industries are investing much effort in this pioneering research first funded by AOSTRA. Funding for this project is $97,160 over two years.

36. Dr. N.C. Wardlaw of the University of Calgary is doing microscopic studies of sandstones and carbonates obtained from Alberta reservoirs to determine the effects of factors such as wettability and pore geometry on fundamental processes important to enhanced recovery of bitumen and heavy oil. An important part of this work is developing methods to improve the performance of AOSTRA's patented AWACT process for recovering heavy oil. Funds for this project and earlier ones amount to $537,384 over six years.

Professors periodically report the progress in their research and assign ownership of their technology to AOSTRA. At the Technical Review Meeting and Seminar held each year in October, the professors and their students present the current results of their research. This year more than 170 senior scientists and engineers from the oil industry, universities, and government attended the meeting to learn about the progress on 49 current and completed projects.

The AOSTRA/University/Industry ACCESS Program provides companies with reports of current research, regular interaction with researchers, non-exclusive technology use rights, and an opportunity to participate in project evaluation and selection. An Associate Membership category in this program allows companies to obtain membership privileges with somewhat restricted

participation in evaluation of projects and technology use rights. In 1991, 20 companies participated in the program as full or associate members at annual fees of $50,000 or $10,000, respectively.

In 1992, the economy of Alberta's oil industry and of AOSTRA is severely reduced and funding of this program will be reduce by more than a factor of two to $1,224,699. Consequently, fewer than 12 companies may participate in this program and the Technical Review Meeting and Seminar may be postponed.

11 AOSTRA–ALBERTA RESEARCH COUNCIL PROGRAM

AOSTRA continues to support laboratory research on oil sands and heavy oils at the Alberta Research Council (ARC). This research generally consists of the following major program areas:

- AOSTRA/ARC/CANMET/Industry Joint Research on in situ recovery
- AOSTRA/ARC Joint Regional Geological Studies
- AOSTRA/ARC Joint Hydrocarbon Upgrading Research
- AOSTRA Strategic Research
- Sample Bank

These programs are carried out under multiyear agreements with the provision for an annual review of the project plan and budget. AOSTRA's contribution to the programs in the 1991/92 fiscal year amounts to approximately $2.93 million, which is reduced by $0.59 million from the previous year's budget.

11.1 AOSTRA/ARC/ CANMET/Industry Joint Research on In Situ Recovery

The original five-year AOSTRA/ARC/ Industry Joint Research in Advanced Thermal Recovery Program (1986 – 1991) expired on March 31, 1991. It was this program that established an infrastructure of world-class interdisciplinary expertise and hardware which can be utilized to significantly improve in situ recovery of heavy oil and bitumen resources in Alberta. A new five-year program was launched April 1, 1991, focusing on the "mission-oriented" applied research which aims at significantly improving in situ recovery of heavy oil and bitumen resources. The objective of this research, evaluation, and industry technology transfer program is to reduce the cost of production. The problems that remain to be solved in order to ensure commercial viability are beyond the capabilities of a single organization. Consequently, there is a need for a collective, coordinated effort which focuses on important problems and breakthrough technologies that can improve production throughout the industry. The AOSTRA/ARC/Industry Research Program was initially established as a partnership through which government and industry could combine their efforts in a cost-effective and productive way. CANMET, representing the Canadian government, later participated in the program as a co-sponsor. The name of the program has since changed to the AOSTRA/ARC/ CANMET/Industry Research Program.

In the first year of the new program, a major part of the effort was directed towards high-risk research to develop novel recovery methods with the potential for economic rewards. Several process development projects explored novel recovery strategies that would improve the economics of thermal recovery in existing and future pilots. The fundamental section focused on improving the understanding and representation of fluid movements and matrix responses that control the recovery of oil. The technical program includes 12 projects, organized into three groups:

- High-risk projects
- Improving existing processes
- Fundamental projects

The program was funded at $4 million in 1991/92, approximately 33 person-years of effort. The multidisciplinary project teams include reservoir and chemical engineers, colloid scientists, geochemists, physicists, and numerical modelers. Many of the experiments require precision measurements at high pressures and temperatures in static and flow systems. Scaled models, visual models, and physical simulators are used for larger scale, multidimensional flow experiments, and numerical modeling is employed extensively throughout the program.

Participating oil companies play a major role in directing the program at both the management and research levels, and their staff provide a direct route by which research results may be transferred back to their companies. AOSTRA and ARC each contribute $1.2 million to the program and CANMET contributes $390,000. Participating oil companies pay an annual membership fee of $75,000 each. The total annual budget is set at $4 million. AOSTRA maintains the responsibility for ownership and sale of

technology. The technology advances and achievements in the first year of the 1991/96 research program are listed below:

- The scoping physical model experiment with immiscible CO_2 gas has shown encouraging results. An increase in oil production of about 14% was attributed to the injection of immiscible CO_2 gas.
- A number of surfactants were evaluated for their ability to create water-continuous emulsions with heavy oils ranging in viscosity from 2200 to 22 000 mPa·s. The surfactant, "Flothin F10," supplied by Pfizer, was found to be the most suitable with the oils tested.
- Novel oil recovery processes were developed using supercritical fluid extraction (SFE) and have been shown to have good potential for reservoir application. The extraction process results in an effective upgrading of the recovered oil.
- Visualization experiments on flows of oil-saturated sand to simulate production for the formation demonstrated that rupture (slip) bands developed progressively from the slits as sand was produced. In the formation, shear bands likely provide paths where flow resistance is diminished, giving rise to increased oil production.
- An analytical model was developed to represent fluid displacement in a disturbed region near the wellbore. The model provides a method for calculating the volumetric flow to and from the wellbore under a given pressure drop between the well and the reservoir.
- An idealized case study showed that microbial heating could raise the temperature of a reservoir by as much as 20°C.
- The iron bacteria *Leptothrix and Sphaerotilus* were identified as promising candidates for selective plugging of highly permeable zones.
- 1-D combustion experiments and the incorporation of oxidation kinetics into the CMG model STARS were preliminary steps in the design of a 3-D combustion facility and experimental strategy. The 3-D combustion facility is now operational and is being used to test top-down combustion processes using horizontal wells.
- Gravity drainage parameters and mechanisms were quantified using a new 2-D visualization cell. The shape of steam chamber was a strong function of production fluid control and showed uneven growth along horizontal wells. During the initialization stage of the gravity process, permeability effects were shown to be dominant in controlling process performance.
- Novel injection and production strategies for enhancing gravity drainage and improving heat distribution.
- Cyclic steam experiments using the "scaled" model showed that gravity drainage was dependent on steam quality. Experiments also demonstrated that a higher recover could be expected if a horizontal rather than a vertical fracture was to develop.
- Scoping experiments for the cyclic steam fracturing experiments demonstrated the importance of well-to-well interactions in controlling fractures.
- Gelled foams were shown to be capable of producing a strong, stable block in a porous medium at temperatures of up to 200°C. X-ray CT experiments have yielded information on the placement and breakdown of gel-foams.
- Conditions required for formation of water-in-oil emulsions in porous media were quantified. Results can be expressed as a threshold capillary number for emulsification which depends on the water-to-oil viscosity ratio.
- Based on the properties shown by calcite inhibitors at high temperatures, a new two-step technology is being tested for cyclic steam applications.
- The use of fiber optics inside an autoclave has provided the means of directly monitoring inhibitor efficiency by following the precipitation of calcite and silica scale under conditions which simulate near-well and wellbore conditions.
- Smectite from Cold Lake does not swell significantly, even in very dilute produced waters; smectite from the shale of the same area swells in aqueous fluids similar to produced waters at Cold Lake. This may explain poor productivity in shale-rich portions of the reservoirs.
- The likelihood of smectite swelling was related to the composition of smectites and the injection and reservoir fluids. This information is used to construct novel "swelling" diagrams to evaluate potential formation damage.
- The parametric analysis of oil mobilization at the pore level indicates a strong preference for the water-wet state in the case where the oil phase is much more viscous than the water.

11.2 Regional Geology Studies

The AOSTRA/ARC Regional Geological Program has been extended for another three years from 1991 to 1994 to cover initially three multiyear projects. This program is designed to complete outstanding resource characterization and reservoir modeling work, so that much of the previous work completed in the Athabasca area will be concluded and synthesized. A final publication will consolidate all of the existing data on the Athabasca oil sands deposit and present resource maps that are consistent over the entire area. An electronic data base will foster future oil sands development by providing fundamental data to the public and private sectors. Existing reports on Athabasca South and West would be edited and refined for publication in the AOSTRA Technical Publication Series.

The second project in the program is to characterize and model the geology of the McMurray Formation to optimize bitumen production from both surface mining and in situ operations. Closely spaced cores and mineface data from the Syncrude mine are used to document the geological variability within the McMurray Formation. The detailed geological framework can then be used to model flow within the formation for application to existing in situ projects, such as the UTF Project. As the McMurray Formation is the main reservoir for exploitation in the Athabasca area, this study will be directly applicable to existing in situ and mining operations and provide a detailed geological data base for future oil sands development.

The 1991/92 budget was originally set at $800,000 (AOSTRA was to contribute $400,000); however, it was reduced by 50% in the middle of the year due to budget restraints.

The AOSTRA/ARC Regional Geological Program has attained many significant achievements spanning a wide range of activities in the past. The program has received strong support from the public and from the private sector and has been recognized as providing a basic service to the industry.

11.3 AOSTRA/ARC Joint Upgrading Research Program

The five-year AOSTRA/ARC Joint Upgrading Research Program, which began in 1987 and expired March 31, 1992, focused primarily on investigations of the mechanisms of coke formation from bitumen upgrading and on the development of the new catalytic hydrocracking high-conversion process. AOSTRA contributes $400,000 annually to the $800,000 annual budget of the program.

The 1991/92 upgrading research program focused on the areas of high-conversion process development, control of coke formation, and evaluation of novel catalysts. Within these areas, five specific projects were designed to extend the expertise accumulated over the last few years and to provide technical supports that complement AOSTRA's $(HC)_3$ process development and the Upgrading Demonstration Facility. The five projects were:

- Secondary Hydrotreating of High Conversion $(HC)_3$ Product
- Novel Catalytic Processes
- Mechanisms of Coke Formation
- Reactor Dynamics
- Catalyst Activity in Recycle Operation.

The research efforts continued to advance expertise in the above-noted areas. Described below are the respective project objectives and the highlights of their findings.

Secondary Hydrotreating of High-Conversion $(HC)_3$ Products

This project was designed to study the removal of heteroatoms from the virgin Cold Lake feedstock distillate and $(HC)_3$ cracked distillates of the same feedstock, and to assess the quality of the hydrotreated products (naphtha, jet fuels, light and heavy gas oils) relative to the pipeline specifications for the Shell Scotford Refinery and the Canadian General Standard for aviation fuels.

The preliminary results of hydrotreating using Criterion 424 catalyst show that the hydrotreated products met most of the product specifications. The exceptions were that the sulphur content in the naphtha marginally exceeded the specification and jet fuels failed to meet the smoke point requirement.

Novel Catalytic Processes

The main objective of the project was to develop a class of catalysts with known improved performance for primary and secondary upgrading.

A series of aluminum pillared interlayered clays (PILCs) and silico-aluminophosphates (SAPOs) were prepared as the novel supports for nickel/molybdenum- and iron-based upgrading catalysts. Significant advancements were made in improving the total catalyst pore volumes, desired pore size distributions, and metals dispersion. However, the performances of these catalysts have not undergone a corresponding level of activity improvement.

Even in the best case, the prepared catalysts attained only 60% of the activity observed for commercial catalysts.

Mechanisms of Coke Formation

The objectives were:

- to develop an in situ technique for monitoring coke formation;
- to determine the solubility parameters for the various components affecting coke formation;
- to study the transformation of catalyst precursor into active catalyst.

The project completed two demonstration tests on the application of catalyst precursor and fluid compatibility in suppressing coke formation where Syncrude Research sent their scientific observers. This was done in conjunction with the AOSTRA/ Syncrude Joint Venture: Improvement for Reducing Coke Deposition in Thermal Upgrading Processes. This joint venture originated from the research results obtained by the Mechanisms of Coke project.

Proper catalyst precursor dispersion was demonstrated to be an important factor affecting process performance.

Reactor Dynamics

This project had the objective of providing technical support for the development of the AOSTRA $(HC)_3$ process.

Reactor hydrodynamics were studied using radioactive tracers method and a reaction mechanism was proposed for the performance of the hydrocracking reactor. Radioactive tracers experiments were extended to predict the fraction of the feed and hydrocracked product evaporated in the reactor. Some engineering studies were made to investigate the unsteady-state behavior and the energy balance of the $(HC)_3$ hydrocracking reactor. Energy balance studies were extended to include study of a temperature control mechanism utilizing hydrogen quenching.

Catalyst Activity in Recycle Operation

The main objective was to study the feasibility of recycling the homogeneous catalyst used in the $(HC)_3$ process.

Cost analysis done by AOSTRA shows that catalyst recycling would contribute to improving the economics of the $(HC)_3$ process. This project developed the in situ Fourier transform infrared (FT– IR) spectroscopy technique to monitor the activity of the fresh and recycled molybdenum catalysts. This technique has the advantage of bypassing the time-consuming laboratory experiments for determining catalyst activity.

11.4 AOSTRA Strategic Research Program

The Strategic Research Program is designed to provide a confidential forum for applied proprietary research and development to meet AOSTRA's specific needs in all areas of operation. The program has three broad objectives:

- To apply concepts, results and insights gained from laboratory research to field situations.
- To address specific problems from field operations.
- To investigate and evaluate AOSTRA technology for potentially broader application to resource development.

The program is fully funded by AOSTRA; approximately $1.05 million was expended in the 1991/92 fiscal year. The program committee, which is composed of representatives from three different directorates of AOSTRA, as well as ARC, is continuously monitoring progress of the program and ensuring the program conforms with AOSTRA's priorities. Research projects, which have been identified by the program committee, are listed below:

1. Gravity drainage enhancement for application in multilayered reservoirs.
2. Artificial lift: improving pumping efficiencies for thermal recovery (partially supported by the Strategic Research Program through the AOSTRA/Industry Thermal Pump Committee).
3. Thermal testing of geotextile sand control devices.
4. Hot water extraction improvement monograph.
5. Improvement for reducing coke deposition in thermal upgrading processes (support of AOSTRA/ Syncrude joint venture).
6. Development of hydrocracking technology.
7. Produced water treatment.

Much progress has been achieved in every aspect of the program in 1991/92. Attention should be drawn to the progress of the first project (*i.e.*, gravity drainage enhancement for application in mululayered reservoirs). The novel Branched Wells Assisted Gravity Drainage (BWAG) strategy would be

able to produce all reservoir zones at rates and final recovery, comparable to homogeneous reservoirs. It has great potential for use in complex reservoir situations and a patent is being pursued.

In 1991/92, the original budget was set at $1.2 million. However, during the year, the budget was reduced to $1.05 million; projects 2 and 3 were affected by the budget cut.

11.5 Sample Bank

In addition to the research and development programs described earlier in this report, AOSTRA also continued to support the Sample Bank Project at ARC in 1991/92. Approximately $80,000 was expended. The prime purpose of the Sample Bank is to support research and development of all phases of oil sands and heavy oil technology by providing "standard" oil sands, bitumen, and other related samples to research communities around the world. During the year, the Sample Bank distributed a total of 440 tonnes of materials with a value of $17,332. The Sample Bank is working towards self-sufficiency without support from AOSTRA in future years.

12 PROGRAMS AT OTHER INSTITUTIONS

12.1 Centre for Frontier Engineering Research (CFER)

CFER core programs are addressing wellbore equipment and associated problems. These include wear problems in oil production wells, casing formation interaction, tubing joint integrity, sucker rod tubing wear, and slant well directional control. AOSTRA actively participates in this program and funded $35,000 of its cost in 1991/92.

A multiclient program to qualify Grade 55 casing for thermal well application was finalized with the issue of a report in March 1992. The project demonstrated that, with proper engineering, Grade 55 casing will perform satisfactorily in thermal applications. The project cost of $615,000 was funded by eight industry partners and AOSTRA. AOSTRA's cost was $30,000.

AOSTRA and four industry participants funded a study, "Downhole Oil/Water Separator Development Project," to confirm the present state of oil/water separation technology and determine if it can be applied in a downhole environment with economic benefits. The project was initiated in February 1992 and is expected to be completed early in the 1992/93 fiscal year. Total cost is estimated to be $25,000 with AOSTRA's share being $5000.

A significant multiclient three-year project, "Mechanisms and Management of Sand Production" began its second year in January 1992. Its objective is to generate an understanding of sand production and improve the economics of oil recovery. Well file data collection, selection of data interpretation methods, definition of laboratory test objectives, and numerical simulation to address borehole stability have been the major activities to date. The project is being managed by CFER and conducted at CFER, the University of Waterloo, and the University of Alberta. It is funded by AOSTRA, five industry participants, and NSERC. Total project cost is expected to be $1,523,500 with AOSTRA's share being $150,000.

12.2 Computer Modelling Group

AOSTRA and Computer Modelling Group (CMG) continued in cooperation in reservoir simulation research and entered into a new five-year program beginning April 1, 1991. In the year 1991/92, AOSTRA supported the program with $280,000. The program has the following overall objectives:

- To develop new simulation technologies to increase recovery from Alberta reservoirs;
- To provide advanced simulation technology for AOSTRA and ARC research and field pilot;
- In partnership with ARC, to model new physical processes;
- To expedite applying new simulation technology with industry.

In 1991/92, CMG undertook the development of a comprehensive flexible grid system based on control-volume finite elements (CVFE) which addresses the deficiencies of the Cartesian grid system. The CVFE grids are used to simulate a Steam-Assisted Gravity Drainage (SAGD) process with two horizontal wells. It enhances the modeling accuracy of SAGD.

CMG also developed a dual-fluid concept in 1991/92 to deal with the concerns that fluids are not fully mixed in gridblocks as a result of viscous fingering, channeling due to heterogeneities, and gravity overrides. The dual-fluid concept was validated using the adverse-mobility displacement data in the literature.

In the third area of interest, CMG applied the concept of dispersed components to the modeling of emulsions and foams. The ability to model the flow of dispersed

components realistically and efficiently impacts on all aspects of heavy oil production, both in the laboratory and in the field.

CMG also provided simulation support to AOSTRA and ARC in the use of the thermal simulator, "STARS," and the black-oil simulator, "IMEX." Updates for all of CMG's simulators were delivered in October 1991.

12.3 Petroleum Recovery Institute

AOSTRA provided continued support to the Petroleum Recovery Institute (PRI) during the fiscal year 1991/92 by matching industry contributions to a maximum of $1 million. PRI was also financially supported by 22 industry members and CANMET during the fiscal year.

PRI is currently conducting research in four major areas related to enhanced oil recovery. The areas of research are gas flooding (miscible displacement), sweep efficiency improvement, heavy oil recovery, and chemical flooding. The results of this work are available to AOSTRA and industry members for potential field applications.

In 1991/92, AOSTRA participated in a multiclient study being conducted by PRI to investigate the occurrence and significance of fines and pyrobitumen in selected carbonate reservoirs. AOSTRA also participated with industry in the purchase of a magnetic resonance imaging (MRI) machine by PRI in the fall of 1991. The MRI machine will be used to provide analytical data for PRI core research projects as well as for industrial contract research. The MRI machine is the only one in Canada currently being used for petrological studies.

PRI provides technical expertise to AOSTRA for special laboratory studies and technical performance analysis of AOSTRA projects. AOSTRA has an agreement with PRI to patent and act as exclusive licensing agent for technology developed at PRI, with AOSTRA as the owner of the technology.

12.4 Saskatchewan Research Council Multiclient Research Program

During the fiscal year 1992/92, AOSTRA continued to participate in a number of multiclient research programs being conducted by the Saskatchewan Research Council (SRC). AOSTRA receives the results of research being conducted in the areas of emulsion research, horizontal well technology, miscible oil displacement, in situ combustion, and enhanced recovery of heavy oil by CO_2 injection. In 1991/92, AOSTRA funded SRC to the extent of $75,000 and received the results of the $1.8-million research program conducted at SRC.

13 INTERNATIONAL PROGRAMS

Introduction

AOSTRA continued an active international program during 1991/92 with the signing of five Memorandums of Understanding (MOUs) with Nigeria, Romania, Pakistan, Brazil, and the United Kingdom, and with negotiations underway with Ecuador, India, and Albania. AOSTRA staff have also been actively involved in a number of international activities, both domestically (hosting of incoming visitors and trainees) and abroad (participating in fact-finding missions and technical conferences/exhibits).

AOSTRA continues to work closely with Alberta Economic Development and Trade and with the International Trade Centre of Industry, Science and Technology Canada in promoting Alberta goods and services around the world. This is achieved primarily through AOSTRA's contacts, credibility, and acceptance that were developed from its MOU activities, and also by active participation in trade shows, seminars, and trade delegations. AOSTRA also continues to promote the sale of its own technology and is having success in developing sales for the ATP technology as well as laying the groundwork for sales of several in situ technologies.

UNITAR

The 5TH UNITAR Conference on Heavy Crude and Tar Sands was held in Caracas, Venezuela from August 4–9, 1991. AOSTRA was well represented as co-sponsor of the conference, and with an exhibit that attracted many people. The UNITAR conference was a major success with the largest attendance in the history of the event, excellent papers, and extensive and well-represented exhibit and participation from around the world.

The semiannual meeting of the UNITAR Information Centre for Heavy Crudes and Tar Sands was held in New York in December 1991. Major decisions were to redirect the Centre to a more entrepreneurial role in promoting training sessions, workshops, and technical exchange activities with funding generated on a project-by-project basis and to move away from UNITAR to an

association with UNDTCD (United Nations Department of Technical Cooperation and Development) as the Center's contact with the UN. Further decisions with respect to the Center's relationship with the UN and its association with UNDTCD will be made at the next Governing Board meeting, which will be held in Calgary in June 1992.

China

The major achievement in 1991/92 has been to convince the China National Petroleum Corporation (CNPC) to participate in the UTF project. Seven years of effort by the International group have resulted in CNPC's joining the UTF. The agreement will be signed in May 1992, and calls for the establishment of CNPC office in Calgary with AOSTRA's help.

A technical cooperation agreement between AOSTRA and the China Petrochemical Corporation (SINOPEC), a state-owned company responsible for downstream operations within the Chinese petroleum industry, was signed under the auspices of the MOU signed in 1990. One of the joint projects in this agreement calls for joint sponsorship of an International Symposium on Heavy Oil and Residue Upgrading and Utilization. The Fushun Research Institute of Petroleum and Petrochemicals (FRIPP), a subsidiary of SINOPEC, was mandated to organize this symposium on behalf of SINOPEC. AOSTRA provided the typing of the manuscripts to a camera-ready form for the proceedings. The symposium will be held in Fushun City from May 5–8, 1992 and will be attended by more than 250 participants from 10 countries. Future cooperation with SINOPEC will also be discussed during the visit to China by AOSTRA's delegation in conjunction with the international symposium. One of the main agenda items was SINOPEC's participation in the development of AOSTRA's $(HC)_3$ upgrading process.

There have been numerous activities between AOSTRA and CNPC, including its subsidiaries. In 1991/92, CNPC actively participated in our University Access Program and the ARC Access Program by sending representatives to attend the annual technical review meetings and seminars. Some laboratory and field visits were also organized in conjunction with these meetings. AOSTRA also discussed with CNPC the promotion and transfer of ATP technology for oily waste treatment to CNPC. (The use of ATP technology for recovering hydrocarbons from oil shale deposits that are interbedded with coal seams were also discussed with China's coal industry.) A seven-member delegation from Liaohe Oilfield was hosted by AOSTRA in January 1992 and toured major heavy oil developments and heavy oil research institutions in Alberta.

AOSTRA staff assisted the China-Alberta Petroleum Centre to develop a training program and course outlines for the Modern Heavy Oil Recovery Technology.

Russia

AOSTRA representatives met with three different groups from Russia during the UNITAR conference. Discussions held with MNTK, the All-Union group we have a MOU with, centered on a joint symposium in 1992 and the opening of a joint office in Moscow. The second group, VNIGRI, is organizing an international conference in October 1992 in St. Petersburg, and asked for assistance from AOSTRA. Discussions with TATNEFT representatives dealt with upgrading and refining their heavy oils, where they asked AOSTRA to have a technical audit of their process.

As part of the changes that occurred in the former Soviet Union since August 1991, the republics (now independent states) have gained control over their natural resources and the Soviet oil ministry has ceased to exist. For the time being, AOSTRA has postponed the organization of a joint heavy oil symposium with RMNTK (formerly MNTK) to 1993.

AOSTRA was invited to give a paper on the Wolf Lake project at an international conference on unconventional hydrocarbon accumulations to be held in St. Petersburg in October 1992. We have accepted this invitation, and the paper is in preparation. It is planned to discuss the joint Canada/Russia heavy oil symposium for the spring of 1993 following the conference (this symposium would be coordinated with the Romanian one so as to take one group of technical experts to both countries).

We have received an enquiry from Hungary regarding the use of the ATP in Western Siberia to clean soil contaminated by oil leaking out of pipelines. It was directed to UMATAC for advice on a response, which is now in preparation.

Hungary

Work started at the University of Calgary's Combustion Laboratories on the joint study with the Hungarian National Oil Trust, which has proposed to conduct up to $200,000 worth of

research at Dr. Moore's laboratory. This is an extension of last year's combustion tube tests aimed at developing a process applicable to light oils. The tests are jointly sponsored by AOSTRA and the Hungarian Hydrocarbon Institute. This, together with research work in Hungary, is to form the basis for a field application in Hungary of the combustion technology developed jointly by AOSTRA and Hungary. AOSTRA will be kept informed of the progress of this work, and receive all research reports in exchange for sending the Canadian experts to Hungary once a year.

Cuba

The final report on the numerical simulation work for the Varadero field, performed during the spring of 1991 at AOSTRA by two Cuban experts, was received and is presently being evaluated. An invitation was also received to visit Cuba in the first quarter of 1992 to conduct further discussions on the improvement of the production of their heavy oil deposits using CO_2. Cuba is interested in the simulation work undertaken at AOSTRA, and in the exploitation of bituminous marls using borehole mining and the ATP technology. Instead of an AOSTRA delegation travelling to Cuba, we have offered to have one of their experts come to Canada for two months to start working on the implementation of CO_2 injection into the Varadero heavy oil field. The Cubans have postponed this for now.

Trinidad

Trinidad and Tobago Oil Company Ltd. (TRINTOC) and AOSTRA personnel met in Caracas during the UNITAR conference, to discuss the application and licensing of ATP technology for Trinidad oil sands exploitation. This meeting was followed up with a field trip to the oil sands properties in Trinidad. Bitumen samples were then sent to UMATAC for batch testing and mineral/chemical characterization tests to be carried out by ARC. All tests have now been completed and the results forwarded to TRINTOC.

A preliminary cost estimate to do a prefeasibility study on an oil sands project in Trinidad using ATP technology will be prepared after review of the results by TRINTOC. TRINTOC is responsible for the submission of an application to CIDA for a financial grant that would contribute to the undertaking of this prefeasibility study.

TRINTOC approached AOSTRA with a request for training of their personnel for their planned oil sands development. After receiving our proposal that contained several options, TRINTOC decided to send a mining geologist for hands-on training in resource assessment and evaluation. A three-month program was prepared with the help of the Alberta Geological Survey and Syncrude, and is scheduled to start in mid-July 1992.

Mr. Alberto Ahow, the Director of the United Nations Centre for Heavy Crude and Tar Sands, has identified several areas which require assistance in Trinidad, and which could create opportunities for Alberta. A meeting was held at AOSTRA to discuss heavy oil pumping/sand control and horizontal well drilling; additional information is being provided to Mr. Ahow as part of this effort for identifying Alberta expertise in these areas.

Venezuela

AOSTRA continues to pursue a number of activities with Venezuela. Progress was reviewed during the UNITAR conference in Caracas and discussed in more detail when a four-person delegation from PDVSA and INTEVEP came to Alberta in November 1991 for the annual Memorandum of Understanding (MOU) meeting (AOSTRA was informed that INTEVEP is taking over from PDVSA the administration and coordination of the activities performed under the scope of the MOU). They visited the UTF site, and spent an entire day at the Alberta Research Council where the emphasis was on familiarizing the Venezuelans with the AOSTRA/ ARC/ CANMET/Industry (AACI) Research Program to try and have them join as members. The main topics discussed at the MOU meeting were: upgrading (Venezuela's HDH process and AOSTRA's $(HC)_3$ process, as well as the Demonstration Centre); exchange of students/scientists; AWACT tests in Venezuela; and use of the ATP technology for refinery sludge cleanup.

The bi-annual meeting of the MOU with Venezuela was cancelled in March 1992 due to travel restrictions. INTEVEP continues to express interest in joining the AACI program, and AOSTRA continues to evaluate the HDH process for bitumen upgrading.

Nigeria

An MOU was signed with the Committee on the Implementation of the Bitumen Project (CIBP), the Presidential Commission in charge of developing the Nigerian oil sands, during a fact-finding mission to Nigeria in May 1991. Nigeria has a rich oil sands deposit containing in excess of 30 billion barrels of bitumen. The deposit outcrops that can be mined, and has sections suitable for in situ recovery. Further discussions were held with the CIBP during the UNITAR conference.

Discussions revolved around sampling and analysis, setting up analytical facilities in Nigeria, and developing a preliminary exploration program. Correspondence was exchanged with APROFIM, a major construction company affiliated with CIBP, on the same topics, and names of Canadian groups and consultants were given to them to help them start the work program. The CIBP subsequently decided to purchase laboratory equipment for performing their own bitumen sample analyses. With the help of the Alberta Research Council (ARC), a comprehensive list of equipment, along with costs and technical literature was assembled and sent to them. ARC will purchase the equipment on their behalf. The CIBP has asked us about arranging training of their staff in the testing and analysis of bitumen samples as part of the MOU.

Professor S. Ola, from Benin University, visited AOSTRA for three weeks in early July 1991. His interests in oil sands lie principally in the use of this material for road paving purposes. His itinerary was coordinated with Alberta Transportation to include all aspects of bitumen extraction and processing.

USA

Representatives from AOSTRA, CANMET, Saskatchewan Energy and Mines, and US/DOE met for the annual Canada/U.S. Memorandum of Understanding (MOU) for cooperation in tar sands and heavy oil R&D. The meeting was held in Regina in early October 1991, with field visits to Sceptre's Tangle Flags horizontal well project, Husky's Bi-Provincial Upgrader, Co-op's New Grade refinery, and the Saskatchewan Research Council's laboratories. The main topics discussed at the MOU meetings were: heavy oil/oil sands funding in Canada and U.S.; upgrading R&D, and location of upgraders (field *versus* central site); CO_2 supply for Canadian EOR projects from the U.S.; horizontal wells; and in situ combustion workshop. Results from the retort tests on the diatomite samples performed at UMATAC were forwarded to the members of the Canada/U.S. MOU for cooperation in tar sands and heavy oil R&D upon completion. An international in situ combustion (ISC) workshop and brainstorming session is being jointly organized by AOSTRA and SUPRI in Tulsa in April 1992 in conjunction with the SPE/DOE meeting, under the terms of the MOU. It will attract more than 45 renowned experts, with heavy participation from industry, to discuss the future of ISC.

AOSTRA hosted the Governor of Oklahoma on behalf of the Department of Energy. His visit included a trip to the oil sands in Fort McMurray. On another occasion, energy regulators from Kansas and Texas were briefed on technological advances and achievements in the Alberta oil sands.

Japan

As part of the MOU activities between AOSTRA and the Japanese National Research Institute for Pollution and Resources (NPIPR), three papers were jointly written and published on the effect of mild hydrotreating of Athabasca bitumen on the product distribution of fluid catalytic cracking (FCC). This upgrading work is performed in Japan with direct involvement by AOSTRA.

AOSTRA received two visitors from the Japan Oil Engineering Co., which is affiliated with JAPEX. They were given information on AOSTRA technology, ranging from UTF/SAGD to ATP to upgrading.

AOSTRA staff will visit Japan in May 1992 as part of the promotion of the Upgrading Demonstration Centre. They are planning to visit seven companies and organizations to promote the $(HC)_3$ technology and Japanese participation in the Upgrading Demonstration Centre.

Argentina

Ten kilograms of asphaltite samples from a mine site in western Argentina have been analyzed and tested. Characterization analyses at ARC indicated that the samples are mainly organic in nature (less than 10% mineral matter). Batch retort tests at UMATAC were successful using a sand heat carrier at a 3:1 ratio. Upon discussion of these results with Asphaltum S.A., they are anxious to set up a 15-tonne-per-hour ATP plant at the mine site. Preliminary scope and capital cost estimates for such a processing plant in Argentina have been prepared by UMATAC and sent to Argentina for their consideration.

Brazil

Following a few years of effort, the Research and Development Center of the Brazilian National Oil Company (CENPES/PETROBRAS) has signed an MOU with AOSTRA. Brazil is interested in conducting a joint project with AOSTRA, with particular interest in steam assisted gravity drainage from surface wells. They would like to have an AOSTRA specialist spend some time in Brazil defining the project, followed by an extended stay of a Brazilian expert in Canada to work on the project.

Ecuador

The AOSTRA visit to Ecuador to finalize signing of the MOU following the 5TH UNITAR conference in Caracas has been postponed. AOSTRA still intends to pursue this activity as Ecuador has a heavy oil/oil sands deposit of perhaps 200 billion barrels.

India

Two representatives of the Institute of Reservoir Studies/Oil and Natural Gas Commission of India (IRS/ONGC) visited AOSTRA in connection with UNDP project IND/90/024. They were interested in discussing training requirements for some of their staff for various EOR projects. We were not able to accommodate their needs.

France

Further discussions were held with Institut Français du Pétrole representatives during the UNITAR conference in Caracas. The French would like to cooperate with AOSTRA, but are primarily looking for members to join their various research consortia (we have received several proposals but were not able to respond favorably to their requests).

Germany

A meeting was held with representatives of KRUPP, a large German materials handling company, who are interested in future mining prospects in the Alberta oil sands. As well, two visitors from Germany, looking to invest into the Alberta oil sands to secure feedstock for their refineries, were hosted by AOSTRA. Unfortunately, due to their very tight schedule and short stay in the province, a trip to the UTF could not be arranged.

Albania

Through our contacts and relationships with the Hungarian Hydrocarbon Institute, we have learned that Albania has in excess of 200 million tons of heavy oil (12 – 16°API) at depths varying from 100 to 1500 m in the Driza field alone. This downdip deposit, with 23% average porosity and 500 mD average permeability, is a good prospect for Alberta technology: in situ combustion with oxygen at the top of the reservoir could be combined with cold heavy oil and sand production using progressive cavity pumps at the bottom of the reservoir. The Hungarians have offered to introduce us to the Albanians.

Romania

A three-person delegation from the Research and Design Institute for Petroleum (ICPT – Cîmpina) was hosted by AOSTRA for two weeks in July 1991. This group is now the official Romanian government oil and gas representative, and we signed an MOU on scientific and technical cooperation. They were introduced to various AOSTRA and Alberta technologies. During their visit, it was agreed to hold a joint symposium in the fall of 1992 in Romania.

A visit to Romania was made in October 1991 to start the planning of the symposium, discuss the Romanians' areas of interest, so as to select the Canadian experts that will be best suited for the trade mission which will go to the symposium and tour some field sites.

The Joint Canada/Romania Heavy Oil Symposium, co-sponsored by AOSTRA and ICPT – Cîmpina, has been postponed to the spring of 1993. A preliminary budget has been drafted, and selection of the experts has started. To date, 10 companies have shown an interest in participation. External Affairs and International Trade Canada have agreed in principle to defray some of the costs associated with this event.

Norway

AOSTRA was contacted by IKU/SINTEF, a Norwegian Research Institute with whom we have an memorandum of understanding. They are interested in sending one of their experts to Canada for three months as part of an exchange program under the terms of the MOU. The candidate, Mr. Olav Selle, is proposing to undertake three-phase relative permeability experiments under various wettability conditions. This project will make use of the x-ray CT scanner and single-beam system not available in Norway, and will be undertaken at the Alberta Research Council in Clover Bar, starting around mid-May 1992.

United Kingdom

A two-person delegation from the Petroleum Science and Technology Institute (PSTI) in Edinburgh visited Alberta in September 1991 for one week. They spent one day with AOSTRA, visiting the Library and Information Services and discussing areas of cooperation. A draft MOU was given to them for consideration. Following this visit, PSTI signed the MOU on scientific and technical cooperation.

An AOSTRA representative attended the 12TH International Workshop and Symposium of the IEA Collaborative Project on Enhanced Oil Recovery held in Bath. Following the meeting, the

delegates had the opportunity to visit the facilities of AEA Petroleum Services in Winfrith (the site where the U.K. Atomic Commission has its major research facility).

A three-day visit was arranged for Dr. Andrew Millington, University of Salford EOR Group, who was interested in meeting/visiting people/ projects dealing with in situ combustion and oil upgrading.

Taiwan

AOSTRA staff joined the Alberta Environmental Trade Mission in a visit to Taiwan in December 1991 as a result of an invitation from the Alberta Department of Economic Development and Trade. AOSTRA's representation in the mission was highly regarded by the environmental industry as well as the local media. Presentations on ATP technology and AQPS have generated a great deal of interest among many environmental companies. The versatility of AOSTRA's technology base, and the high technical and scientific competence of AOSTRA staff have created a positive impact, and were a necessary asset to the Alberta mission, enhancing its technical credibility. In connection with the environmental mission, a staff member also met with the Chinese Petroleum Corporation in Taiwan to review the $(HC)_3$ process and the proposed Upgrading Demonstration Centre concept. A positive response to the concept and useful discussions were generated as a result of the meeting.

Malaysia and Singapore

AOSTRA staff met the Malaysian Environmental Trade Mission in the fall of 1991 and the Singapore Environment Mission in March 1992 at the Economic Development and Trade offices in Edmonton. The ATP technology for treating hydrocarbon-contaminated wastes was introduced and discussed with several members of both groups. They all indicated a strong interest in the technology. A site visit to the the Calgary ATP pilot plant was arranged for the Malaysian group. As Malaysia (including Singapore) is located halfway between the Middle East and the Far East on major tanker routes, a large quantity of oil sludge has been accumulated when the tankers have been cleaned up and repaired in the area. The companies represented at those trade missions saw the potential of using the ATP technology for cleaning up harbors.

Hong Kong

A Hong Kong productivity council delegation visited the AOSTRA office in March 1992, where a presentation was made to them. A lengthy discussion on the ATP technology for waste treatment followed, and its application in Hong Kong was explored and identified.

Pakistan

A memorandum of understanding on scientific and technical cooperation was signed with the Oil and Gas Development Corporation of Pakistan during the UNITAR conference. This country has heavy oil reserves that could be exploited by AOSTRA technology. The Chief Reservoir Engineer of the Oil and Gas Development Corporation of Pakistan visited AOSTRA in November 1991 to present information on some of Pakistan's light and heavy oil fields. AOSTRA has offered to provide assistance in heavy crude upgrading technology, and in identifying Canadian contacts for all aspects of oil recovery using horizontal wells.

Azerbaijan

The oil sands samples from the Kirmaku field received last summer have been tested at UMATAC, and a report on the results of these tests, as well as preliminary scope and capital cost estimates for an ATP plant in Azerbaijan, is in preparation. The Institute of Deep Oil and Gas Deposits (IPGNGM) of the Azerbaijan Academy of Sciences are anxious to have the information and results regarding the processibility of this material using the ATP as they are being pressured by their government to start the exploitation of the Kirmaku deposit.

Madagascar

Discussions for cooperation in the area of horizontal well technology started during the UNITAR conference in Caracas. We are presently waiting to obtain more information from Madagascar to pursue this opportunity. As a follow-up to the discussions started during the UNITAR conference, we have received an invitation to visit Madagascar during the spring/summer of 1992. Their main interest is in horizontal well technology for enhancing recoveries from their Bemolanga tar sands and Tsimiroro heavy oil deposits.

14 TRAINING PROGRAMS

Due to budget restrictions, AOSTRA has had to severely restrict its training programs which were designed to give young Albertans experience in hydrocarbon recovery and processing. No activities were conducted under its NAIT/SAIT and University Summer Student Program and activities under its Co-op and New Graduate Assistance Programs were severely restricted.

Co-op Program

This program employs engineering students who are on the industrial portion of their co-op training program. Students are employed at AOSTRA's Calgary office for periods of four or eight months.

New Graduate Assistance Program

This program gives new university graduates in engineering and geology an opportunity to work for two years and obtain their work experience required for professional registration. Six recent graduates are employed at AOSTRA's Calgary and Edmonton offices under this program.

15 INDUSTRIAL POSTDOCTORAL FELLOWSHIP PROGRAM

In 1983 AOSTRA initiated its Industrial Postdoctoral Fellowship Program which was designed to assist the transition of postdoctoral researchers from an academic to an industrial environment. During the two-year term of the award, valued at $22,500 per year, the AOSTRA Industrial Fellow conducts a research project in the laboratory of the sponsoring company which provides the space, equipment, and support personnel required for the proper conduct of the research.

During fiscal year 1991/92 there were three holders of the award:

- Dr. Khoon-Sin Tan is responsible for evaluation of Nuclear Magnetic Resonance (NMR) technology for use by Syncrude through the design and completion of a variety of experiments and to act as a technical interface with external laboratories carrying out contract NMR work.
- Dr. Laurie J. Danielson is working on the fundamental aspects of the sludge disposal problem at Syncrude with the aid of scanning electron microscopy, X-ray diffraction, and NMR spectroscopy.

16 INVENTORS GRANT ASSISTANCE PROGRAM

The Inventors Grant Assistance Program (IGAP), first implemented in 1983, was continued during fiscal 1991/92. The purpose of IGAP is to encourage and assist inventors to develop inventions beyond the idea and concept stage so that conventional funding for commercialization may be obtained. Amounts to a maximum of $50,000 may be awarded to individuals or companies for use in developing inventions. AOSTRA does not earn any use rights to the inventions and the only requirement on the part of the inventor is a commitment to use the funds in the development of the invention and to supply both accounting and technical reports to AOSTRA.

This continues to be a popular program with a total of 12 applications being reviewed during the year. Three of these applications were approved for funding as follows:

- PBL Machinery Ltd., $20,000, development of an adjustable stabilizer for directional and horizontal drilling.
- J. Nenniger, $25,000, development of a downhole hot oil heater.
- Anderson and Associates, $21,000, development of a device for hardening oilfield tubing and casing.

17 TECHNOLOGY EXCHANGE

Queen's University (PARTEC) has received an AOSTRA licence to further develop the microwave catalytic conversion of methane to ethylene and the microwave catalytic conversion of methane to alcohols.

18 PUBLICATIONS DEPARTMENT

The Publications Department continued to produce a high number of publications throughout the year. AOSTRA's Technical Publication Series, which was up to Series 7 in the last reporting period, is now at Series 14:

- Series 8 is the second installment of a four-part series from the Alberta Geological Survey and it deals with resource characterization of the Athabasca south region.
- Series 11 presents thoroughly tested analytical methods for training.
- Series 12 is a monograph dealing with understanding the colloidal phenomenon and its implications to the oil sands industry.
- Series 13 is a manual of hydraulic fracturing theory and in situ stress determination methods.
- Series 14 describes industrial procedures for extraction and some recent fundamental research.

AOSTRA Technical Publication Series

1. *Syncrude Analytical Methods For Oil Sand and Bitumen Processing*
2. *The Thermodynamic and Transport Properties of Bitumens and Heavy Oils*
3. *Aquathermolysis: A Synopsis of Work on the Chemical Reaction Between Water (Steam) and Heavy Oil Sands During Simulated Steam Stimulation*
4. *Oil Sands Composition and Behaviour Research*
5. *A Review of Analytical Methods For Bitumens and Heavy Oils*
6. *AOSTRA Technical Handbook on Oil Sands, Bitumens and Heavy Oils*
7. *Resource Characterization of the McMurray/Wabiskaw Deposit in the Athabasca Central Region of Northeastern Alberta*
8. *Resource Characterization of the McMurray/Wabiskaw Deposit in the Athabasca South Region of Northeastern Alberta*
9. *Resource Characterization of the McMurray/Wabiskaw Deposit in the Athabasca West Region of Northeastern Alberta (to be published at a later date)*
10. *Resource Characterization of the McMurray/Wabiskaw Deposit in the Athabasca Oil Sands Area: A Synthesis (to be published at a later date)*
11. *Syncrude Analytical Methods Manual For Bitumen Upgrading*
12. *Fundamentals of Electrokinetic and Interfacial Phenomenon With Applications to Oil Sands*
13. *AOSTRA Mini-Frac Manual*
14. *The Alberta Oil Sands: Industrial Procedures For Extraction, and Some Recent Fundamental Research*

The Publications Department was involved in preparing the proceedings of two AOSTRA/China conferences. The Second China–Canada Heavy Oil Symposium papers were translated and these proceedings will be available this summer. The papers for the International Symposium on Heavy Oil and Residue Upgrading were prepared to a camera-ready stage and then shipped to China where they were printed.

We are presently working on two Russian books. *Bitumen deposits of Kazakhstan* will be available this fall and *Thermic methods for increasing petroleum production* will be worked on during the year.

In April 1991, we were commissioned to publish the proceedings of the 5TH UNITAR International Conference on Heavy Crude and Tar Sands. A four-volume set of hardcover books, containing over 2000 pages, was produced. Work has since started on publication of a fifth volume to go with these proceedings. It will contain the speeches and addresses, a list of participants, and the question-and-answer sessions; we expect publication to be completed this fall.

We have been involved in producing numerous other booklets and brochures including AOSTRA's Annual Report. We continue to produce the TARpaper and the AOSTRA Journal of Research. We recently prepared the papers for the Fueling the Future conference, a joint AOSTRA/Canadian Heavy Oil Association meeting to be held in June 1992. A catalogue of AOSTRA publications was prepared. This booklet contains descriptions of all AOSTRA publications and was prepared with the intent of providing a handy reference to publications which may be useful to researchers. It is hoped that it will put more of the important information that AOSTRA has into the hands of the people it was intended for.

Throughout the year, the Publications Department has continued to assist other departments and organizations with the production of promotional material. We have produced many cards, plaques, brochures, ads, etc., and have responded to many requests for design and production assistance

19 CONFERENCES, TRADE EXHIBITS AND WORKSHOPS

International

5TH UNITAR International Conference on Heavy Crude and Tar Sands

- August 4 – 9, 1991
- Caracas, Venezuela

This exhibit featured AOSTRA technology for in situ thermal recovery, enhanced recovery bitumen extraction, underground mining, waste treatment, and technology information services.

Geotechnica '91

- September 18 – 21, 1991
- Cologne, Germany

In collaboration with Canada External affairs, AOSTRA was prominent in promoting the AOSTRA Taciuk Processor (ATP) as a technology suited to oily waste soil treatment. Considerable interest in the ATP was generated and market opportunities were identified and reported.

Domestic

The following activities were entered into during the 1991/92 program year to further the knowledge of AOSTRA technology in Canada:

Intercan 91 Oil and Gas Show

- June 4 – 6, 1991
- Edmonton, Alberta

The AOSTRA exhibit was a major feature of this show highlighting the UTF and ATP projects. Considerable interest in the exhibit was evident by the number of persons that visited.

Fort McMurray Oil Sands 91 Trade Show

- June 18 – 19, 1991
- Fort McMurray, Alberta

AOSTRA supplied an information outlet to this event that provided handout technical literature and other information regarding AOSTRA activities.

International Waste Cycle 1991

- October 29 – 30, 1991
- Toronto, Ontario

This exhibition was a combined activity of three organizations, all involved with solid waste management. AOSTRA and UMATAC jointly sponsored a technical exhibit featuring the ATP project at Wide Beach, N.Y. The exhibit was judged to be one of the best at the conference and attracted several high-quality interviews regarding the ATP performance.

Environment Trade Fair

- April 10 – 2, 1992
- Edmonton, Alberta

This exhibition was the second event to be held in Edmonton to offer local residents an opportunity to meet suppliers of environmental products, services, and technologies. AOSTRA participated with an exhibit that featured the ATP; produced water treatment; Air Quality Prediction System (AQPS); and tailings pond treatment. The show was a good opportunity to provide information about and foster good will towards AOSTRA.

75TH Canadian Chemical Conference and Exhibition

- June 1 – 2, 1992
- Edmonton, Alberta

This technical exhibition is a component of the 75TH Canadian Chemical Conference, May 31 – June 4, 1992 at the Edmonton Convention Centre. AOSTRA will be participating with an information centre in support of ALIS (AOSTRA Library and Information Services).

Fort McMurray Oil Sands Trade Show

- June 23 – 24, 1992
- Fort McMurray, Alberta

AOSTRA will feature the UTF and ATP exhibits at this trade show to emphasize these major achievements in oil sands technology.

Alberta Centre for Upgrading Technology (ACUT)

AOSTRA embarked upon a program in 1991 to examine a concept to establish a centre for upgrading technology. The purpose of the centre is to focus upon new technology breakthroughs for cost reduction in the upgrading of bitumen/heavy oil.

A canvass of 21 operating oil companies and provincial government departments was undertaken in early 1992 to determine the interest by industry to share in the establishment of such a centre. To date, the concept has been received favorably by industry due to their recognition of potential for improving upgrading costs and of the value of research towards synthetic crude oil quality development.

20 AWARDS

Karl A. Clark Distinguished Service Award

This award is presented to individuals who have made important contributions to the overall realization of the commercial potential of Alberta's oil sand resources. Currently the award is made by an external panel of five distinguished Canadians who review the nominations received in an open competition.

In 1991, the award was presented to Dr. Frederick W. Camp of Sun Oil Company, who played a major role in the process, piloting, design, construction and commissioning of the Great Canadian Oil Sands plant at Fort McMurray. The award consisted of a distinctive sculpture created specifically for this award by an Alberta artist, and the establishment of a $10,000 scholarship fund at Athabasca University for the Dr. Frederick W. Camp Memorial Scholarship in Science and Engineering.

Chairs

In January 1990, Dr. William Costerton of the Department of Microbiology of the University of Calgary, was awarded the NSERC Chair of Bacterial Biofilm Research. This important award was made in recognition of his internationally recognized contributions to the study of fouling of surfaces by bacteria. Dr. Costerton is responsible for many significant inventions including a patented process for selectively plugging subterranean formations. This process for increasing oil production from reservoirs and for containing contaminated ground waters is owned by AOSTRA.

The term of the Chair is five years and annual support amounting to $604,600 is provided, 50% by a consortium of 18 companies, including AOSTRA, and a matching 50% by the National Science and Engineering Research Council (NSERC). AOSTRA's support for the Chair amounts to $40,000 per year.

21 AOSTRA LIBRARY AND INFORMATION SERVICES (ALIS)

AOSTRA Library and Information Services' multidisciplinary team of technical information officers and support staff in both Edmonton and Calgary provides efficient public and confidential information and technical consulting on oil sands, heavy oil, and enhanced recovery processes.

The Alberta Oil Sands Index (AOSI) encompasses all aspects of Canadian and international oil sand development, ranging from fundamental research, geology and exploration, to recovery, upgrading, transportation and marketing.

The Heavy Oil/Enhanced Recovery Index (HERI) encompasses all aspects of Canadian and international heavy oil development. Limited coverage of enhanced recovery of conventional oil is also included, with emphasis on Canadian development and field-applied technology.

AOSI and HERI are available both in online and microfiche formats. Hard copies pertaining to these public indices are also available.

AOSTRA's confidential information is also computerized and a hard-copy filing system is maintained. This information consists of:

- AOSTRA/Industry Field Pilot Projects;
- AOSTRA/University Research Program;
- AOSTRA Mining, Extraction and Upgrading Projects;
- AOSTRA/ARC/CANMET/Industry Joint Program;
- AOSTRA/ARC Strategic Program;
- AOSTRA/ARC Upgrading Study;
- IGAP (Inventors Grant Assistance Program);
- AOSTRA Invention Disclosures;
- PRI Reports;
- Slurry Tran sport Data Base;
- Sludge Fundamentals Data Base.

In addition, ALIS distributes the TARpaper, the AOSTRA Journal of Research, and all other AOSTRA publications.

Patents

22 AOSTRA PATENTS

The following patents
are assigned to AOSTRA:

A) Canadian Patents

Patent No.	Date Issued	Patent Title
1,102,234	Jun 2/81	Gaseous and Solvent Additives for Steam Injection for Thermal Recovery of Bitumen from Tar Sands (D.A. Redford and M.R. Hanna)
1,120,418	Mar 23/82	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)
1,121,749	Apr 13/82	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk)
1,122,015	Apr 20/82	Process for Microbiologically Leaching Coke (T.R. Jack et al.)
1,134,174	Oct 26/82	Two-Phase Wet Steam Flowmeter (D.S. Scott and E. Rhodes)
1,158,458	Dec 13/83	Variable Drive for Pump Jack (D.L. Buckler)
1,170,444	Jul 10/84	Use of Hydrogen-Free Carbon Monoxide with Steam in Recovery of Heavy Oil at Low Temperatures (J.B. Hyne and J.D. Tyrer)
1,171,382	Jul 24/84	Electrophoretic Process for Separating Aqueous Mineral Suspensions (R.A. Ritter)
1,184,022	Mar 19/85	Use of Surfactants to Improve Oil Recovery During Steam Flooding (E.E. Isaacs and D.R. Prowse)
1,189,444	Jun 25/85	Additive for Inclusion in a Heavy Oil Reservoir Undergoing Steam Injection (J.B. Hyne and P.D. Clarke)
1,206,465	Jun 24/86	Catalytic Sulfur Removal from Hydrocarbons (P.M. Boorman et al.)
1,210,358	Aug 26/86	Process for Upgrading a Heavy Viscous Hydrocarbon (I.H. Lutz) (Acres Davy McKee D.M. International, Inc., Houston, Texas)
1,220,646	Apr 21/87	Two Phase Flowmeter (D.S. Scott and E. Rhodes)
1,225,129	Aug 4/87	Commutator (R.A. Ritter)
1,235,652	Apr 26/88	Method for Obtaining Horizontal Fractures in an Oil Reservoir (T. Harding et al.)
1,239,088	Jul 12/88	Method for Controlling Water Coning in Oil Wells (R.W. Luhning and K.R. Ronaghan)
1,241,293	Aug 30/88	Microwave Induced Catalytic Conversion of Methane to Ethylene and Hydrogen (J. Wan)
1,248,069	Jan 3/89	Apparatus for Continuously Separating Particulate Solids from Liquid Suspensions (R.A. Ritter)
1,277,936	Dec 18/90	Microbial Process for Selectively Plugging a Subterranean Formation (J.W.F. Costerton et al.)

B) U.S. Patents

Patent No.	Date Issued	Patent Title
4,180,455	Dec 25/79	Process for Thermally Cracking a Heavy Hydrocarbon (W. Taciuk)
4,271,905	Jun 9/81	Gaseous and Solvent Additives for Steam Injection for Thermal Recovery of Bitumen from Tar Sands (D.A. Redford and M.R. Hanna)
4,280,879	Jul 28/81	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk)
4,285,773	Aug 25/81	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk — Lloydminster Version)
4,306,961	Dec 22/81	Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk — Tarsand Version)
4,312,234	Jan 26/82	Two-Phase Flowmeter (D.S. Scott and E. Rhodes)
4,438,218	Mar 20/84	Catalytic Sulfur Removal from Hydrocarbons (P.M. Boorman et al.)
4,454,023	Jul/Aug/84	Process for Upgrading a Heavy Viscous Oil (Hydrocarbon) (I. Lutz) (Acres Davy McKee D.M. International, Inc., Houston)
4,458,759	Jul 10/84	Use of Surfactants to Improve Oil Recovery During Steam Flooding (E.E. Isaacs and D.R. Prowse)
4,487,264	Dec 11/84	Use of Hydrogen-Free Carbon Monoxide with Steam in Recovery of Heavy Oil at Low Temperatures (J.B. Hyne and J.D. Tyrer)
4,501,648	Feb 26/85	Electrophoretic Process for Separating Aqueous Mineral Suspensions (R.A. Ritter)
4,506,733	Mar 26/85	Additive for Inclusion in a Heavy Oil Reservoir Undergoing Steam Injection (J.B. Hyne and P.D. Clarke)
4,574,038	Mar 4/86	Microwave Induced Catalytic Conversion of Methane to Ethylene and Hydrogen (J. Wan)
4,574,643	Mar 11/86	Two Phase Flowmeter (D.S. Scott and E. Rhodes)
4,623,203	Nov 18/86	Commutator (R.A. Ritter)
4,623,442	Nov 18/86	Apparatus for Continuously Separating Particulate Solids from Suspensions (R.A. Ritter)
4,718,489	Jan 12/88	Pressure-up/Blowdown Combustion — A Channelled Reservoir Recovery Process (R.J. Hallam and J.K. Donnelly)
4,800,959	Jan 31/89	Microbial Process for Selectively Plugging a Subterranean Formation (J.W.F. Costerton)
4,846,275	July 11/89	Recovery of Heavy Crude Oil or Tar Sand Oil or Bitumen from Underground Formation (A.S. McKay)
4,890,482	Jan 2/90	Method and Apparatus for Measuring Fluid Viscosity (B.B. Maini)

B) U.S. Patent (cont'd)

Application No.	Date Filed	Patent Application Title
5,056,596	Oct 15/91	Recovery of Bitumen or Heavy Oil In Situ by Injection of Hot Water or Low Quality Steam Plus Caustic and Carbon Dioxide (A.S. McKay)
5,060,727	Oct 29/91	Method for Improving Enhanced Recovery of Oil Using Surfactant-Stabilized Foams (L. Schramm et al.)
5,060,730	Oct 29/91	Water-Wetting Treatment for Reducing Water Coning in an Oil Reservoir (Kisman et al.)
5,062,482	Nov 5/91	Piezometer Actuator Device and Method for its Installation in a Borehole (J. Graham et al.)
5,062,483	Nov 5/91	Treatment for Reducing Water Coning in an Oil Reservoir (Kisman et al.)
5,074,358	Dec 24/91	Surfactant-Stabilized Foams for Enhanced Oil Recovery (W. Rendall et al.)

C) Venezuela Patents

Patent No.	Date Issued	Patent Title
3729	Jun 10/80	Process for Microbiologically Leaching Coke (J. Zajic et al.)
1299/82	Jul 21/82	Use of Hydrogen-Free Carbon Monoxide with Steam in Recovery of Heavy Oil at Low Temperatures (J.B. Hyne and J.D. Tyrer)
3714	Aug 1/86	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk)
3970	Aug 5/86	Gaseous and Solvent Additives for Steam Injection for Thermal Recovery of Bitumen from Tar Sands (D.A. Redford and M.R. Hanna)
4102	Aug 7/86	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)
5278	Mar 18/87	Wet Combustion Process (D.W. Bennion et al.)
6576	Apr 28/87	Additive for Inclusion in a Heavy Oil Reservoir Undergoing Steam Injection (J.B. Hyne and P.D. Clarke)

D) Mexico Patents

Patent No.	Date Issued	Patent Title
153182	Oct 24/79	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

E) European (EEC) Patents

Patent No.	Date Issued	Patent Title
0-028-666	Apr 6/83	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk) (Belgium, France, Italy, Netherlands, and U.K.)
79,302542.0		(Sweden)
29-65-154.5		(Germany)
0076882	Jul 17/85	Two-Phase Flowmeter (D.S. Scott and E. Rhodes)
84.301888.8	Mar 20/84	Process for Upgrading a Heavy Viscous Oil (Hydrocarbon) (I. Lutz) (Acres Davy McKee DM International, Inc., Houston)

F) Romania Patents

Patent No.	Date Issued	Patent Title
78671	Oct 31/81	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

G) Turkey Patents

Patent No.	Date Issued	Patent Title
22129	May 13/86	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

H) Japan Patents

Patent No.	Date Issued	Patent Title
1,248,976	Jan 25/85	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)
1,580,021		Two Phase Flowmeter (D.S. Scott and E. Rhodes)

PRIOR COMPANY PATENTS (for which AOSTRA has acquired certain licensing rights)

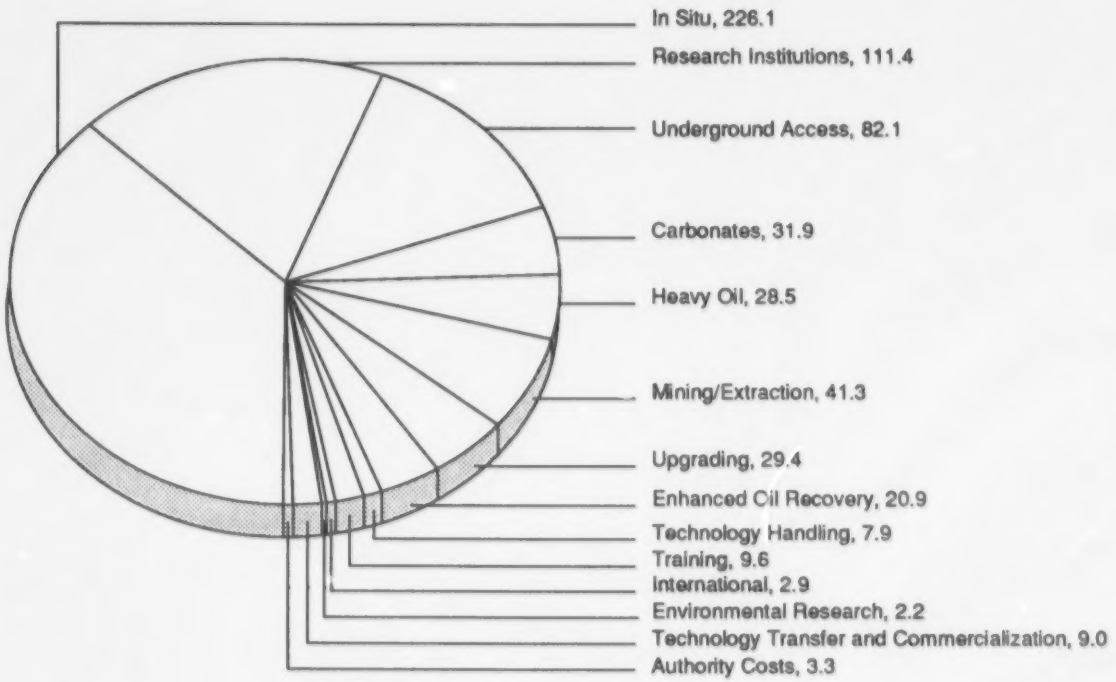
A) Canadian Patents

	Canadian Patent No.	Date Issued	Date Filed	Related U.S. Patent No.	Patent Titles
1.	1,125,649	Jan 15/82	Dec 19/79	4,234,042	Direct Combustion Stimulation of a Producing Well
2.	1,118,341	Feb 16/82	Sep 14/79	4,272,487	Indirect Thermal Stimulation of Producing Wells

B) U.S. Patents

	U.S. Patent No.	Date Issued	Date Filed	Related Canadian. Patent No.	Patent Titles
1.	3,964,547	Jun 22/76	Oct 29/74	972,679	Use of Tar as a Diverter in Steam Operations
2.	4,147,213	Apr 03/79	–	–	Combustion Air Injection Well
3.	4,234,042	Nov 18/80	Jun 11/79	1,125,649	Direct Combustion Stimulation of a Producing Well
4.	4,272,487	Jun 23/81	Jan 01/79	1,118,341	Indirect Thermal Stimulation of Producing Wells

Commitments from AOSTRA Research Fund to March 31, 1992
($ Millions)



Tables

Table 1

Oil Sands Technology and Research Fund
Summary of Funds Committed and Disbursed
As at March 31, 1992

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/91 to March 31/92	Balance
Institutional Research				
Alberta Research Council				
— Information Centre — ALIS	$ 8,165,168	$ 7,325,150	$ 835,982	$ 4,036
— Oil Sands Research Centre	31,623,886	30,214,114	1,416,086	(6,314)
— Sample Bank	2,017,788	1,937,788	78,162	1,838
— Regional Geological Program	5,675,280	5,415,380	212,857	47,043
— Hydrocarbon Program	4,101,849	3,666,684	400,058	35,107
— Strategic Research Program	8,644,256	7,444,221	1,050,000	150,035
Inventors Assistance Grant	1,552,920	1,222,211	125,135	205,574
University Contracts	38,220,300	34,084,398	2,210,458	1,925,444
Professorships and Chairs	4,196,109	4,001,494	40,000	154,615
Lectureship Program	34,000	14,489	8,600	10,911
ARC Access Program	25,000	16,201	8,799	–
University Access Program	175,000	173,100	(2,878)	4,778
Program Planning and Evaluation	522,000	417,606	–	104,394
Hydrogen Industry Council	125,000	125,000	–	–
Centre for Frontier Engineering Research	140,000	75,000	30,000	35,000
Computer Modelling Group	3,040,000	2,360,000	680,000	–
Unitar Conference	379,000	292,249	5,099	81,652
Unitar Management Operations	315,067	268,895	41,172	5,000
Completed Projects	2,465,271	2,465,271	–	–
	$ 111,417,894	$ 101,519,251	$ 7,139,530	$ 2,759,113
Training Activities				
General	$ 3,575,000	$ 3,049,450	$ 184,480	$ 341,070
New Graduate Assistance Program	865,000	666,622	110,495	87,883
Post Doctoral Fellowships	348,000	207,290	–	140,710
Scholarships and Fellowships	4,810,000	3,902,044	256,555	651,401
	$ 9,598,000	$ 7,825,406	$ 551,530	$ 1,221,064
Mining and Extraction				
Retorting — UMATAC	$ 20,752,208	$ 19,687,208	$ 839,170	$ 225,830
Saskatchewan Research Council	20,000	15,000	–	5,000
Terra Energy SESA Project	500,000	473,420	–	26,580
Esso Resources OSLO Project	6,962,500	6,562,239	150,000	250,261
Burning Rock Oil Ltd.	60,000	14,428	45,572	–
Syncrude Canada Limited	955,000	881,448	–	73,552
Completed Projects	12,057,429	12,057,429	–	–
	$ 41,307,137	$ 39,691,172	$ 1,034,742	$ 581,223

Table 1

Oil Sands Technology and Research Fund
Summary of Funds Committed and Disbursed
As at March 31, 1992

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/91 to March 31/92	Balance
In Situ Oil Sands				
Peace River — Shell	$ 75,039,351	$ 74,948,148	$ 72,301	$ 18,902
Athabasca				
— Amoco	24,000,000	23,792,526	–	207,474
— Amoco/Petro-Canada	20,322,617	17,929,173	765,310	1,628,134
— Husky Oil Operations	52,861,000	51,608,110	1,585,038	(332,148)
Cold Lake				
— BP	24,200,000	23,960,011	–	239,989
— BP/Petro-Canada	1,499,250	1,150,150	–	349,100
— Bow Valley Industries	14,700,000	13,816,696	48,173	835,131
— Suncor — Fort Kent	400,000	115,957	–	284,043
Simtech Consulting	75,260	70,796	4,464	–
Fekete Thermal Software Program	100,000	97,216	–	2,784
Simons Consulting — Coning Project	521,200	133,383	367,878	19,939
Engineering Studies Program	525,000	463,265	57,215	4,520
Site Studies	375,000	126,617	61,887	186,496
Peace River Task Force	100,000	31,177	(5,000)	73,823
Centre For Frontier Engineering — Casing Study	30,000	18,000	12,000	–
CFER — Sand Control	150,000	25,000	50,000	75,000
CFER — Oil/Water Separator	5,000	–	3,000	2,000
Mazzei Oil and Gas	495,000	460,211	29,633	5,156
Mobil Oil Canada	87,000	–	87,000	–
Golder and Associates	40,000	–	22,500	17,500
Petro-Canada — Hangingstone Project	50,000	–	–	50,000
Completed Projects	10,564,382	10,564,382	–	–
	$ 226,140,060	$ 219,310,818	$ 3,161,399	$ 3,667,843
Underground Access				
Athabasca				
— UTF Project	$ 76,956,947	$ 74,234,304	$ (1,224,489)	$ 3,947,132
— Completed Projects	5,108,264	5,108,264	–	–
	$ 82,065,211	$ 79,342,568	$ (1,224,489)	$ 3,947,132
Carbonate Trend				
Buffalo Creek				
— Union Oil	$ 31,585,000	$ 31,316,303	$ 47,281	$ 221,416
Completed Projects	308,082	308,082	–	–
	$ 31,893,082	$ 31,624,385	$ 47,281	$ 221,416

Table 1

Oil Sands Technology and Research Fund
Summary of Funds Committed and Disbursed
As at March 31, 1992

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/91 to March 31/92	Balance
Heavy Oil				
Petro-Canada	$ 14,308,046	$ 14,033,470	$ (20,730)	$ 295,306
Alberta Energy Company	7,941,500	7,480,660	(12,194)	473,034
Norcen Energy Ltd.	4,130,000	4,129,320	(455,215)	455,895
PanCanadian Petroleum	1,915,000	1,112,961	542,096	259,943
Completed Projects	239,674	239,674	–	–
	$ 28,534,220	$ 26,996,085	$ 53,957	$ 1,484,178
Enhanced Recovery Conventional Oil				
Vikor Resources Ltd.	$ 3,900,000	$ 3,729,191	$ (117,077)	$ 287,886
Amoco — Cessford	2,462,500	2,423,967	4,926	33,607
Petroleum Recovery Institute	7,776,252	6,587,567	1,187,000	1,685
Robinson Slim Tube Test	192,573	186,033	6,442	98
Saskatchewan Research Council	300,000	225,000	75,000	–
PRI EOR Initiatives Program	400,000	399,478	500	22
PRI Pulp Paper Study	20,000	13,798	–	6,202
Pfizer Rundell Horizontal Well	800,000	–	256,743	543,257
Beau Canada Petroleum Ltd.	500,000	–	476,262	23,738
Gulf/Fenn — Big Valley Project	130,000	–	87,406	42,594
Strategic Research EOR	300,000	118,050	19,255	162,695
Parker Well Productivity	100,000	–	–	100,000
Amoco — Combustion Study	30,190	–	30,190	–
Petrolphysics Inc. Study	30,000	3,806	24,999	1,195
Hycal Miscibility Study	35,000	–	20,000	15,000
Norwest Coalbed Methane Study	12,500	–	11,988	512
Simtech 3-D Geomechanical Model	49,820	–	47,124	2,696
Donnelly Gasification Study	50,000	–	–	50,000
Completed Projects	3,823,641	3,823,641	–	–
	$ 20,912,476	$ 17,510,531	$ 2,130,758	$ 1,271,187
Bitumen Upgrading				
Residue Utilization Project	$ 1,398,232	$ 1,234,794	$ 1,500	$ 161,938
AURD Upgrading Demonstation Pilot	315,000	195,453	115,982	3,565
Canadian Energy — Co-Processing	297,500	169,776	127,724	–
Coal-Oil Processing	50,000	39,550	7,819	2,631
Petro-Canada/CANMET Project	450,000	398,571	–	51,429
CANMET — Pitch Recycle Project	425,000	–	425,000	–
CANMET Co-Processing Research Consortium	450,000	–	300,000	150,000
HIC — Hydrogen Separation System	25,000	–	12,500	12,500
ATP — Hydrotreating Test	25,000	–	1,380	23,620
RTM Engineering Ltd.	49,000	26,942	22,058	–
Lummus Crest Inc.	1,444,000	1,274,242	506	169,252
Completed Projects	24,479,806	24,479,806	–	–
	$ 29,408,538	$ 27,819,134	$ 1,014,469	$ 574,935

Table 1

Oil Sands Technology and Research Fund
Summary of Funds Committed and Disbursed
As at March 31, 1992

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/91 to March 31/92	Balance
Technology Transfer and Commercialization				
Technology Transfer and Commercialization	$ 1,310,000	$ 907,183	$ 401,149	$ 1,668
AOSTRA/Taciuk — Demonstration — Umatac/SPP — Commercialization	1,500,000	1,027,505	472,495	–
— ATP — Commercialization	461,000	225,197	235,604	199
Comparative Economic Evaluation	300,000	17,759	71,674	210,567
Five-Ton/Hour — UMATAC ATP Processor	5,000,000	275,611	4,029,998	694,391
AWACT — Demonstrations	94,000	–	59,304	34,696
AOSTRA/Syncrude SAGD Comparative Study	100,000	–	95,984	4,016
AOSTRA/Suncor SAGD Comparative Study	75,000	–	76,221	(1,221)
Atomic Energy of Canada Ltd. Fuel Study	125,000	–	16	124,984
	$ 8,965,000	$ 2,453,255	$ 5,442,445	$ 1,069,300
Environmental Research				
WTC Water Treatment Project	$ 700,000	$ 545,560	$ 141,690	$ 12,750
Monenco	67,665	67,665	–	–
Sludge Fundamentals Consortium	400,000	122,929	206,876	70,195
Canadian Petroleum Association Oily Solids	30,000	20,000	–	10,000
Carbon Dioxide Disposal	350,000	13,526	114,254	222,220
Environmental Audits	85,000	–	5,838	79,162
Environmental Research Centre	250,000	250,000	–	–
Shell Peace River — Metal Loss	300,000	–	236,655	63,345
	$ 2,182,665	$ 1,019,680	$ 705,313	$ 457,672
Technology Handling				
Data Base Administration	$ 4,824,165	$ 4,388,808	$ 228,330	$ 207,027
AOSTRA Journal	599,773	522,626	32,502	44,645
Patent Costs	1,470,000	1,179,683	292,088	(1,771)
AOSTRA Publication Series	166,900	103,398	31,047	32,455
AOSTRA Technical Handbook	100,000	91,639	2,970	5,391
AOSTRA 15-Year Review	645,510	641,010	–	4,500
Completed Projects	91,865	91,865	–	–
	$ 7,898,213	$ 7,019,029	$ 586,937	$ 292,247
International Activities	$ 2,862,575	$ 2,340,551	$ 404,632	$ 117,392
Authority Costs	$ 3,318,708	$ 2,979,173	$ 284,445	$ 55,090
Totals	$ 606,503,779	$ 567,451,038	$ 21,332,949	$ 17,719,792

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Seventeen-Year Summary
For the years ended March 31

	1992	1991	1990
Revenue			
Alberta General Revenue Fund	$ 7,000,000	$ 25,394,000	$ 29,349,000
Alberta Heritage Savings Trust Fund	–	–	5,151,000
Technology Sales	516,058	534,321	664,347
	$ 7,516,058	$ 25,928,321	$ 35,164,347
Expenditures			
Institutional Research			
Alberta Research Council			
— Information Centre	$ 835,982	$ 830,576	$ 798,006
— Oil Sands Research Centre	1,416,086	1,007,060	1,215,172
— Sample Bank	78,162	119,888	111,760
— Regional Geological Program	212,857	450,626	367,878
— Hydrocarbon Program	400,058	399,956	401,897
— Strategic Research Program	1,050,000	1,572,679	1,447,570
Inventors Assistance Grant	125,135	128,000	200,000
University Contracts	2,210,458	2,762,546	2,373,413
Professorships and Chairs	40,000	40,000	40,000
Lectureship Program	8,600	11,725	2,764
ARC Access Program	8,799	135	–
University Access Program	(2,878)	2,009	(146)
Program Planning and Evaluation	–	32,550	19,276
Hydrogen Industry Council	–	125,000	–
Centre for Frontier Engineering Research	30,000	–	–
Computer Modelling Group	680,000	700,000	1,000,000
UNITAR Conference	5,099	2,441	96,140
UNITAR Management Operations	41,172	58,950	99,853
Completed Projects	–	42,628	–
	$ 7,139,530	$ 8,286,769	$ 8,173,583

1989	1988	1987 and Prior	Total
$ 26,100,000	$ 26,900,000	$ 34,700,000	$ 149,443,000
9,900,000	20,800,000	382,849,032	418,700,032
774,027	1,325,060	16,850,337	20,664,150
$ 36,774,027	$ 49,025,060	$ 434,399,369	$ 588,807,182

$ 714,129	$ 699,180	$ 4,283,258	$ 8,161,131
1,312,005	1,430,990	25,248,886	31,630,199
144,000	153,423	1,408,716	2,015,949
497,521	464,075	3,635,279	5,628,236
388,600	374,383	2,101,849	4,066,743
1,586,666	1,588,050	1,249,256	8,494,221
274,750	109,000	510,461	1,347,346
2,864,891	3,018,722	23,064,827	36,294,857
743	91,120	3,829,630	4,041,493
–	–	–	23,089
5,896	723	9,447	25,000
(2,930)	(95)	174,264	170,224
39,160	–	326,620	417,606
–	–	–	125,000
25,000	25,000	25,000	105,000
220,000	220,000	220,000	3,040,000
23,475	104,588	65,605	297,348
110,092	–	–	310,067
–	17,000	2,405,644	2,465,272
$ 8,203,998	$ 8,296,159	$ 68,558,742	$ 108,658,781

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Seventeen-Year Summary
For the years ended March 31

	1992	1991	1990
Training Activities			
General	$ 184,480	$ 427,005	$ 440,325
New Graduate Assistance Program	110,495	180,222	211,285
Post Doctoral Fellowships	–	39,375	76,875
Scholarships and Fellowships	256,555	258,155	398,076
	$ 551,530	$ 904,757	$ 1,126,561
Mining and Extraction			
Retorting — UMATAC	$ 839,170	$ 935,000	$ 999,332
Saskatchewan Research Council	–	–	15,000
Terra Energy SESA Project	–	96,972	113,673
Esso Resources OSLO Project	150,000	3,150,991	1,955,247
Burning Rock Oil Ltd.	45,572	14,428	–
Syncrude Canada Limited	–	400,000	187,151
Completed Projects	–	658,447	487,418
	$ 1,034,742	$ 5,255,838	$ 3,757,821

	1989	1988	1987 and Prior	Total
	$ 380,107	$ 42,364	$ 1,759,649	$ 3,233,930
	201,518	65,750	7,847	777,117
	22,500	22,500	46,040	207,290
	419,280	418,639	2,407,894	4,158,599
	$ 1,023,405	$ 549,253	$ 4,221,430	$ 8,376,936
	$ 1,004,649	$ 1,378,265	$ 15,369,961	$ 20,526,377
	–	–	–	15,000
	192,389	70,386	–	473,420
	1,118,220	–	–	6,374,458
	–	–	–	60,000
	294,297	–	–	881,448
	345,652	809,657	10,094,037	12,395,211
	$ 2,955,207	$ 2,258,308	$ 25,463,998	$ 40,725,914

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Seventeen-Year Summary
For the years ended March 31

	1992	1991	1990
In Situ Oil Sands			
Peace River			
— Shell	$ 72,301	$ 14,145	$ 16,580
Athabasca			
— Amoco	–	–	–
— Amoco/Petro-Canada	765,310	1,254,145	1,338,535
— Husky Oil Operations	1,585,038	3,273,736	5,220,248
Cold Lake			
— BP	–	1,939	10,105
— BP/Petro-Canada	–	–	–
— Bow Valley Industries	48,173	83,858	761,256
— Suncor — Fort Kent	–	(3,022)	–
Simtech Consulting	4,464	10,336	18,786
Fekete Thermal Software Program	–	–	–
Simons Consulting — Coning Project	367,878	58,180	–
Engineering Studies Program	57,215	85,378	172,495
Sites Studies	61,887	81,436	22,303
Peace River Task Force	(5,000)	–	31,177
Centre For Frontier Engineering	12,000	–	18,000
CFER — Sand Control	50,000	25,000	–
CFER — Oil/Water Separator	3,000	–	–
Mazzei Oil and Gas	29,633	460,211	–
Mobil Oil Canada	87,000	–	–
Golder and Associates	22,500	–	–
Completed Projects	–	41,967	198,894
	$ 3,161,399	$ 5,387,309	$ 7,808,379
Underground Access			
Athabasca			
— UTF Project	$ (1,224,489)	$ 14,875,922	$ 1,443,614
Completed Projects	–	–	–
	$ (1,224,489)	$ 14,875,922	$ 1,443,614

1989	1988	1987 and Prior	Total
$ 175,484	$ 113,028	$ 74,628,910	$ 75,020,448
–	(27,148)	23,819,675	23,792,527
1,372,878	2,069,863	11,893,753	18,694,484
6,641,372	8,700,700	27,772,054	53,193,148
13,971	82,402	23,851,593	23,960,010
–	–	1,150,149	1,150,149
884,225	841,980	11,245,377	13,864,869
–	–	118,979	115,957
9,043	4,299	28,332	75,260
97,216	–	–	97,216
75,203	–	–	501,261
186,274	19,118	–	520,480
22,878	–	–	188,504
–	–	–	26,177
–	–	–	30,000
–	–	–	75,000
–	–	–	3,000
–	–	–	489,844
–	–	–	87,000
–	–	–	22,500
44,226	679,297	9,600,000	10,564,384
$ 9,522,770	$ 12,483,539	$ 184,108,822	$ 222,472,218
$ 3,091,270	$ 3,764,839	$ 51,058,658	$ 73,009,814
–	–	5,108,264	5,108,264
$ 3,091,270	$ 3,764,839	$ 56,166,922	$ 78,118,078

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Seventeen-Year Summary
For the years ended March 31

	1992	1991	1990
Carbonate Trend			
Buffalo Creek — Union Oil	$ 47,281	$ 29,953	$ 57,911
Completed Projects	–	–	–
	$ 47,281	$ 29,953	$ 57,911
Heavy Oil			
Petro-Canada	$ (20,730)	$ 59,311	$ 180,651
Alberta Energy Company	(12,194)	166,182	18,304
Norcen Energy Ltd.	(455,215)	(649,271)	(515,121)
PanCanadian Petroleum	542,096	73,775	70,854
Completed Projects	–	–	–
	$ 53,957	$ (350,003)	$ (245,312)
Enhanced Recovery Conventional Oil			
Vikor Resources Ltd.	$ (117,077)	$ (374,534)	$ (126,283)
Amoco — Cessford	4,926	197,812	144,777
Petroleum Recovery Institute	1,187,000	1,000,000	1,000,000
Robinson Slim Tube Test	6,442	30,043	–
Saskatchewan Research Council	75,000	75,000	75,000
PRI EOR Initiatives Program	500	29,343	26,462
PRI — Pulp Paper Study	–	13,798	–
Pfizer Rundell Horizontal Well	256,743	–	–
Beau Canada Petroleum Ltd.	476,262	–	–
Gulf/Fenn — Big Valley Project	87,406	–	–
Strategic Research EOR	19,255	110,350	7,700
Amoco — Combustion Study	30,190	–	–
Petrolphysics Inc. Study	24,999	3,806	–
Hycal Miscibility Study	20,000	–	–
Norwest Coalbed Methane Study	11,988	–	–
Simtech 3-D Geomechanical Model	47,124	–	–
Completed Projects	–	1,026,786	571,751
	$ 2,130,758	$ 2,112,404	$ 1,699,407

1989	1988	1987 and Prior	Total
$ 80,747	$ 255,743	$ 30,891,950	$ 31,363,585
–	–	308,082	308,082
$ 80,747	$ 255,743	$ 31,200,032	$ 31,671,667
$ (176)	$ (29,809)	$ 13,922,436	$ 14,111,683
774,287	165,875	6,257,071	7,369,525
(548,382)	(1,188,165)	7,030,259	3,674,105
207,119	66,140	695,074	1,655,058
–	–	239,672	239,672
$ 432,848	$ (985,959)	$ 28,144,512	$ 27,050,043
$ 931,941	$ (22,200)	$ 3,320,267	$ 3,612,114
236,523	277,211	1,567,643	2,428,892
700,000	700,000	3,187,567	7,774,567
32,382	116,049	7,559	192,475
65,000	10,000	–	300,000
343,673	–	–	399,978
–	–	–	13,798
–	–	–	256,743
–	–	–	476,262
–	–	–	87,406
–	–	–	137,305
–	–	–	30,190
–	–	–	28,805
–	–	–	20,000
–	–	–	11,988
–	–	–	47,124
266,869	243,631	1,714,604	3,823,641
$ 2,576,388	$ 1,324,691	$ 9,797,640	$ 19,641,288

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Seventeen-Year Summary
For the years ended March 31

	1992	1991	1990
Bitumen Upgrading			
Residue Utilization Project	$ 1,500	$ 18,790	$ 16,023
AURD Upgrading Demonstration Pilot	115,981	195,453	–
Canadian Energy — Co-Processing	127,724	169,776	–
Coal-Oil Processing	7,819	31,182	(16,406)
Petro-Canada/CANMET Project	–	6,370	392,201
CANMET — Pitch Recycle Project	425,000	–	–
CANMET Co-Processing Research Consortium	300,000	–	–
HIC — Hydrogen Separation System	12,500	–	–
ATP — Hydrotreating Test	1,380	–	–
RTM Engineering Ltd.	22,059	26,942	–
Lummus Crest Inc.	506	561,352	712,891
Completed Projects	–	52,407	438,114
	$ 1,014,469	$ 1,062,272	$ 1,542,823
Technology Transfer and Commercialization			
Technology Transfer and Commercialization	$ 401,149	$ 381,455	$ 323,753
AOSTRA/Taciuk — Demonstration — UMATAC/SPP — Commercialization	472,495	1,027,505	–
— ATP — Commercialization	235,604	225,197	–
Comparative Economic Evaluation	71,674	17,759	–
Five-Ton/Hour — UMATAC ATP Processor	4,029,998	275,612	–
AWACT — Demonstrations	59,304	–	–
AOSTRA/Syncrude Process Comparative Study	95,984	–	–
AOSTRA/Suncor Production Comparative Study	76,221	–	–
Atomic Energy of Canada Ltd.	16	–	–
	$ 5,442,445	$ 1,927,528	$ 323,753

1989	1988	1987 and Prior	Total
$ 17,475	$ 161,169	$ 1,021,337	$ 1,236,294
–	–	–	311,434
–	–	–	297,500
24,774	–	–	47,369
–	–	–	398,571
–	–	–	425,000
–	–	–	300,000
–	–	–	12,500
–	–	–	1,380
–	–	–	49,001
–	–	–	1,274,749
740,888	3,531,881	19,716,516	24,479,806
$ 783,137	$ 3,693,050	$ 20,737,853	$ 28,833,604
$ 157,866	$ 44,108	$ –	$ 1,308,331
–	–	–	1,500,000
–	–	–	460,801
–	–	–	89,433
–	–	–	4,305,610
–	–	–	59,304
–	–	–	95,984
–	–	–	76,221
–	–	–	16
$ 157,866	$ 44,108	$ –	$ 7,895,700

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Seventeen-Year Summary
For the years ended March 31

	1992	1991	1990
Environmental Research			
WTC Water Treatment Project	$ 141,690	$ 110,742	$ 59,818
Monenco	–	–	67,665
Sludge Fundamentals Consortium	206,876	122,928	–
Canadian Petroleum Association	–	20,000	–
Carbon Dioxide Disposal	114,254	13,526	–
Environmental Audits	5,838	–	–
Environmental Research Centre	–	250,000	–
Shell Peace River — Metal Loss	236,655	–	–
	$ 705,313	$ 517,196	$ 127,483
Technology Handling			
Data Base Administration	$ 228,330	$ 258,108	$ 311,959
AOSTRA Journal	32,502	38,565	42,340
Patent Costs	292,088	255,109	211,702
AOSTRA Publication Series	31,047	46,006	41,897
AOSTRA Technical Handbook	2,970	143	55,148
AOSTRA 15-Year Review	–	28,833	612,177
Completed Projects	–	–	–
	$ 586,937	$ 626,764	$ 1,275,223
International Activities	$ 404,632	$ 311,499	$ 178,880
Authority Costs	$ 284,445	$ 517,638	$ 228,811
	$ 21,332,949	$ 41,465,846	$ 27,498,937
Excess of Revenue over Expenditures	$ (13,816,891)	$ (15,537,525)	$ 7,665,410
Fund Balance at Beginning of Period	$ 13,840,084	$ 29,377,609	$ 21,712,199
Fund Balance at End of Period	$ 23,193	$ 13,840,084	$ 29,377,609

1989	1988	1987 and Prior	Total
$ 34,599	$ 340,400	$ –	$ 687,249
–	–	–	67,665
–	–	–	329,804
–	–	–	20,000
–	–	–	127,780
–	–	–	5,838
–	–	–	250,000
–	–	–	236,655
$ 34,599	$ 340,400	$ –	$ 1,724,991
$ 122,285	$ 240,945	$ 3,455,510	$ 4,617,137
38,320	46,185	357,217	555,129
110,252	102,620	500,000	1,471,771
5,695	9,800	–	134,445
31,130	5,000	219	94,610
–	–	–	641,010
–	–	91,865	91,865
$ 307,682	$ 404,550	$ 4,404,811	$ 7,605,967
$ 167,161	$ 77,930	$ 1,605,082	$ 2,745,184
$ 217,867	$ 298,554	$ 1,716,303	$ 3,263,618
$ 29,554,945	$ 32,805,165	$ 436,126,147	$ 588,783,989
$ 7,219,082	$ 16,219,895	$ (1,726,778)	$ 23,193
$ 14,493,117	$ (1,726,778)	$ –	$ –
$ 21,712,199	$ 14,493,117	$ (1,726,778)	$ 23,193

Auditor's Report and Financial Statement

Alberta Oil Sands
Technology and Research Authority
Oil Sands Technology and Research Fund
Financial Statements
March 31, 1992

Auditor's Report

Balance Sheet

Statement of Revenue, Expenditure and Fund Balance

Notes to the Financial Statements

AUDITOR'S REPORT

To the Members of the Alberta Oil Sands Technology and Research Authority

I have audited the balance sheet of the Alberta Oil Sands Technology and Research Authority — Oil Sands Technology and Research Fund as at March 31, 1992 and the statement of revenue, expenditure and fund balance for the year then ended. These financial statements are the responsibility of the Authority's management. My responsibility is to express an opinion on these financial statements based on my audit.

I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In my opinion, these financial statements present fairly, in all material respects, the financial position of the Fund as at March 31, 1992 and the results of its operations and the changes in its financial position for the year then ended in accordance with generally accepted accounting principles.

Donald D. Salmon

FCA
Auditor General

Edmonton, Alberta
June 8, 1992

Alberta Oil Sands Technology and Research Authority
Oil Sands Technology and Research Fund

Balance Sheet

As At March 31, 1992

	1992	1991
ASSETS		
Current:		
Cash	$ 3,730,528	$ 24,042,173
Deposits on projects, net (Note 3)	–	646,449
Accounts receivable	$ 2,150,250	$ 874,000
	$ 5,880,778	$ 25,562,622
LIABILITIES AND FUND BALANCE		
Current:		
Accounts payable	$ 4,841,320	$ 9,731,422
Holdbacks payable	1,016,265	1,991,116
	5,857,585	11,722,538
Fund balance	23,193	13,840,084
	$ 5,880,778	$ 25,562,622

The accompanying notes are part of these financial statements.

Alberta Oil Sands Technology and Research Authority
Oil Sands Technology and Research Fund

Statement of Revenue, Expenditure and Fund Balance

For the Year Ended March 31, 1992

	1992	*1991*
Revenue:		
Contributions from the General Revenue Fund	$ 7,000,000	$ 25,394,000
Technology sales	516,058	534,321
	$ 7,516,058	$ 25,928,321
Expenditure:		
Institutional research	$ 7,139,530	$ 8,286,769
Technology transfer and commercialization	5,442,445	1,927,528
In situ oil sands	3,161,399	5,387,309
Enhanced recovery	2,130,758	2,112,404
Mining and extraction	1,034,742	5,255,838
Bitumen upgrading	1,014,469	1,062,272
Environment	705,313	517,196
Technology handling	586,937	626,764
Training activities	551,530	904,757
International activities	404,632	311,499
Authority costs	284,445	517,638
Heavy oil	53,957	(350,003)
Carbonate trend	47,281	29,953
Underground access	(1,224,489)	14,875,922
	$ 21,332,949	$ 41,465,846
Deficiency of revenue over expenditure for the year	(13,816,891)	(15,537,525)
Fund balance at beginning of year	13,840,084	29,377,609
Fund balance at end of year	$ 23,193	$ 13,840,084

Alberta Oil Sands Technology and Research Authority
Oil Sands Technology and Research Fund

Notes to the Financial Statements

March 31, 1992

Note 1 Authority

The Alberta Oil Sands Technology and Research Authority operates under the authority of the Oil Sands Technology and Research Authority Act, Chapter 0–6, Revised Statutes of Alberta 1980.

Note 2 Significant Accounting Policies And Reporting Practices

Expenditures are stated net of recoveries arising from agreements with various participants. Interest earned on cash balances is credited to the General Revenue Fund, and is not reflected in these financial statements. A statement of changes in financial position is not provided as disclosure in these financial statements is considered to be adequate.

Note 3 Deposits On Projects

This amount represents the net excess of cash calls on projects over actual expenditures.

Note 4 Potential Recoveries

The following amounts represent maximum potential future recoveries from the participants in respect of projects funded by the Authority:

	1992	1991
Shell Canada Resources Limited (in situ oil sands)		
— PRISP Project	$ 12,200,000	$ 12,200,000
— Sale of 50% interest in PRISP Project	12,200,000	12,200,000
Norcen International Ltd. (heavy oil)		
— BODO Steam Pilot Project	3,674,000	4,129,000
Vikor Resources Ltd. (enhanced recovery)		
— Joffre Project	3,612,000	3,729,000
	$ 31,686,000	$ 32,258,000

Recovery of these amounts is dependent on generation of net profits by the projects. Due to the uncertainty concerning the amounts of recoveries which may ultimately be generated, these amounts have not been included as a receivable in these financial statements and will be offset against expenditures in the year of receipt.

Note 5 Commitments

The Authority had outstanding commitments as at March 31, 1992 totalling $17,720,000 (1991 $23,764,00) for approved projects.

Note 6 Contingent Liabilities

Legal proceedings

A claim amounting to approximately $2,000,000 has been filed against the Authority. In the opinion of management, the disposition of this claim is not likely to significantly affect the financial position of the Authority. Settlement, if any, will be reflected as expenditure in the year the settlement occurs.

Project abandonment costs

Under joint participation agreements, the Authority may incur certain costs when projects are abandoned. The costs are not reasonably determinable and will be reflected as expenditure in the year they are paid.

Note 7 Administration Costs

The following costs incurred in the administration of the Authority have been borne by the General Revenue Fund and are not reflected in these financial statements.

	1992	1991
Salaries and wages	$ 2,521,265	$ 2,382,809
Employee benefits	403,705	364,464
Rental of property and equipment	386,941	405,954
Fees and commissions	296,137	273,484
Travelling and hospitality	192,746	174,137
Materials and supplies	79,230	94,264
Telephone and telegraph	22,671	18,886
Advertising	17,974	10,154
Freight, express and postage	17,426	8,915
Insurance premiums	4,974	4,569
Equipment maintenance	4,935	27,202
Grants	4,200	4,000
Furniture and equipment purchases	2,370	2,878
	$ 3,954,574	$ 3,771,716

Note 8 Comparative Figures

The 1991 figures have been reclassified where necessary to conform to 1992 presentation.

Note 9 Approval Of Financial Statements

These financial statements were approved by management.